Application of Automatic Position Information Data in Vessel Performance Analysis

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ABSTRACT OF THE
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When a ship's hull and propeller become fouled, the performance of the ship degrades. In these cases, the ship requires more engine power and fuel to reach the same operating speeds. Performance monitoring can be used to analyze the performance of a ship over time and help determine when hull and propeller cleanings should take place. Building on a previous thesis, two performance analysis models were developed in MATLAB. The techniques used in the models developed in this thesis are based upon techniques from the International Towing Tank Conference (ITTC) 1978 performance prediction method and the International Organization for Standardization (ISO) guidelines for assessment of speed and power trials. Both models rely on publicly available Automatic Information System (AIS) data to determine speed and location information. Both models use independent hindcast data for wave conditions, wind conditions, and water properties during the voyages. Both models also filter the data to remove situations which are undesirable to use for performance analysis, such as acceleration and maneuvering. The first model relies on daily fuel consumption readings and analyzes the performance on a per-noon-report basis. The second model relies on onboard auto-logged measurements for engine torque and RPM, and analyzes the performance on a per-auto-logged-period basis. A fuel index is calculated for each analysis point, which allows for tracking of the performance of a ship over time.

Keywords: Performance Analysis, Vessel Performance, Automatic Identification System, AIS

Preface

This study was completed as a Master thesis as part of the Nordic Master in Maritime Engineering program. This thesis is submitted to both the Technical University of Denmark (DTU) and Aalto University as required by the program.

The thesis was supervised by Associate Professor Poul Andersen from the DTU Department of Mechanical Engineering, Section of Fluid Mechanics, Coastal and Maritime Engineering; Professor Pentti Kujala from the Aalto University School of Engineering, Department of Mechanical Engineering; and Team Leader Søren Hattel from the FORCE Technology Department of Hydro and Aerodynamics.

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Finally, I would like to thank my friends and family who stuck with me throughout this thesis process. I would specifically like to thank those who traveled with me, distracted me, and helped me waste time throughout the past few months. Breaks are a necessary part of the thesis process, and I enjoyed every one of them.

Contents

Abbreviations and Symbols

Abbreviations

AIS	Automatic Information System
ECA	Emission control area
GPS	Global Positioning System
HFO	Heavy fuel oil
IMO	International Maritime Organization
ISO	International Organization for Standardization
ITTC	International Towing Tank Conference
JONSWAP	Joint North Sea Wave Observation Project
LCV	Lower calorific value
MDO	Marine diesel oil
MGO	Marine gas oil
MR	Medium Range tanker
PPM	Parts per million
RPM	Revolutions per minute
SFOC	Specific fuel oil consumption
VLCC	Very Large Crude Carrier

Roman Symbols

A_F	Frontal area
B	Breadth
C_B	Block coefficient
C_F	Frictional resistance coefficient in the experienced water conditions
C_{F0}	Frictional resistance coefficient in the standard water conditions
C_χ	Wind coefficient for relative wind direction χ
D	Diameter of the propeller
d_i	Distance traveled in the ith period
DWT	Deadweight
FI	Fuel index
Fr	Froude number
g	Gravitational constant
H_S	Significant wave height
J	Advance ratio
K_Q	Non-dimensional torque coefficient
K_T	Non-dimensional thrust coefficient
k	Wave number
k_{yy}	Non-dimensional lateral radius of gyration

L_{PP}	Length between perpendiculars
LCV_{HFO}	Lower calorific value of heavy fuel oil
LCV_{ISO}	ISO standard lower calorific value of fuel oil
LCV_{MDO}	Lower calorific value of marine diesel oil
LCV_{MGO}	Lower calorific value of marine gas oil
M_{Fuel}	Total fuel oil consumption
M_{FC}	Normalized fuel oil consumption
M_{HFO}	Heavy fuel oil consumption
M_{MDO}	Marine diesel oil consumption
M_{MGO}	Marine gas oil consumption
n	Revolutions per second of the propeller
P_D	Delivered Power
$P_{D,corrected}$	Normalized Delivered Power
P_E	Effective Power
$Q_{measured}$	Measured torque
R	Resistance
R_{ADIS}	Resistance correction due to a change in draft
R_{AS}	Resistance correction due to water properties
R_{AWL}	Added resistance due to waves
R_{AWML}	Added resistance transfer function due to wave induced motion
R_{AWRL}	Added resistance transfer function due to wave reflection
$R_{corrected}$	Normalized resistance of the ship
R_F	Frictional resistance in the experienced water conditions
R_T	Total resistance in the design condition
R_{wave}	Added resistance transfer function due to waves
R_{wind}	Added resistance due to wind
S_η	Wave spectrum
s	Sea water salinity in gm/kg
$SFOC_{ME}$	Specific fuel oil consumption of the main engine
SOC_χ	Speed of current in direction of travel
SOG	Speed over ground
STW	Speed through water
T	Temperature
$T_{measured}$	Measured Thrust
T_M	Mean draft
T_W	Wave period
t	Thrust deduction factor
V	Velocity
W_D	Total work delivered by the ship
W_E	Total effective work done by the ship
w	Wake fraction
w_{adj}	Adjusted wake fraction
X	Sea water salinity in PPM
x	Serial date in the proleptic ISO calendar

Greek Symbols

δ	Displacement in the operating condition
δ_0	Displacement in the design condition
ζ_A	Wave amplitude
η_H	Hull efficiency
η_0	Open water efficiency
η_{RR}	Relative rotative efficiency
η_{trans}	Transmission efficiency
μ	Dynamic viscosity
ν	Kinematic viscosity
ρ_w	Water density in the experienced conditions
ρ_{w0}	Water density in the standard conditions
ρ_{air}	Air density at the current temperature
χ	Heading of the ship
χ_C	Direction of ocean currents
ω	Circular wave frequency

Operators

$\cos$	Cosine
$\sum\limits_{i=1}^{n}$	Summation from i = 1 to n
$\int_0^\infty$	Integral from 0 to infinity
I_1	Modified Bessel function of the first kind of order 1
K_1	Modified Bessel function of the second kind of order 1

1 Introduction

The vast majority of all global trade occurs via ships. At any given time, there are thousands upon thousands of ships operating around the world. The various shipping markets are all subject to many outside influences, and tend to follow a cyclical cycle. When the markets are near their peak, shipping charter rates will be high and profits can be large. However, when the markets are near a low, for example due to a lack of demand or due to overcapacity, margins can be very tight or even negative. At the same time, there are new environmental rules being implemented worldwide. Currently, any ship traveling in emission control areas (ECAs) are required to burn low sulfur fuel, but beginning in 2020, the International Maritime Organization (IMO) will require all ships to use the more expensive, low sulfur fuel everywhere they travel [22]. To reduce operating costs and maximize the profit margins, it is desirable to operate a ship as efficiently as possible.

Performance monitoring techniques can and have been used by ship owners to ensure that the ships are operating efficiently. When a ship is brand new or has been recently drydocked, the hull and the propeller will be clean, the hull coatings will be in the best condition, and the machinery will be operating correctly. However, as a ship ages, hull coatings can fail and equipment performance may degrade. When the ship sits in port or at anchor, the hull and propeller can become fouled (growth of marine organisms on the ship). There can be a significant degradation of performance of the ship over time due to this fouling. Performance monitoring techniques allow ship owners, operators, and charterers to track the performance of a ship over time. Performance monitoring techniques can also allow a ship charterer to be able to compare one vessel versus another to help determine which vessel would be more cost-efficient to charter.

Some newer vessels have specially designed performance monitoring systems installed, which includes the installation of sensors and machine learning systems to evaluate the performance of the ship. However, the majority of vessels do not have performance monitoring systems on board. On these vessels, the only performance information may be manually recorded noon reports, a once-a-day recording of key information such as location, speed, weather conditions, and fuel use. A performance monitoring technique using these noon reports was developed in a previous thesis, described in Section 1.1. However, the inherent assumption that the ship speed and weather conditions do not change over the course of a full day can lead to large errors in the analysis.

Even if ships do not have sensors installed on board, there are other sources of information which can be used to help evaluate the performance of ships. Many large ships and all passenger ships regardless of size are required to fitted with Automatic Identification System (AIS) transponders. The AIS systems automatically reports key information including position, course, and speed over ground, amongst other data. AIS data are automatically transmitted from the vessel every 30 seconds or 3 minutes, depending on the current speed of the vessel. It was objective of this thesis to study the various ways that this high frequency AIS data can be utilized in performance monitoring techniques to improve vessel performance analysis, and to subsequently develop performance analysis models which can analyze vessel performance using these techniques.

This thesis uses data from seven vessels, four Medium Range (MR) tankers and three Very Large Crude Carriers (VLCC), recorded over a period of 19 months between June 2015 and December 2016. The four MRs are sister ships to each other, and the three VLCCs are sister ships to each other, allowing comparison of the ships within each class. Using this data, two different performance analysis models were developed in MATLAB: one for ships with no sensors installed on board, and one for ships with propulsion system sensors. The model for ships without sensors combines data from the noon reports with the AIS data to analyze the performance of the ship during a given noon report. The model for ships with propulsion system sensors analyzes the ship on an hourly basis utilizing automatically-logged data such as shaft torque and propeller revolutions. Both models filter out poor input data (for example, due to recording errors) and times when the ship is in conditions not conducive to vessel performance analysis, and both models also apply corrections for wave and wind conditions, water temperature and salinity, and operating condition of the vessel (i.e. draft) so that the performance of all vessels of the same class can be compared in a normalized condition. These models can then be used by ship owners or charterers to evaluate how each vessel compares to each other or to a charterparty reference value.

The techniques used in the performance analysis models developed in this thesis are based upon techniques from the International Towing Tank Conference (ITTC) 1978 performance prediction method and the International Organization for Standardization (ISO) guidelines for assessment of speed and power trials. This thesis also uses independent hindcast data for wave conditions, wind conditions, and water properties, as opposed to onboard estimates.

1.1 Previous Thesis

This thesis builds on the thesis completed by Jimmie Beckerlee in 2016 [3]. In his thesis, Mr. Beckerlee developed an SQLite database to store all of the measured data as well as the specific vessel information, such as vessel particulars and model test results. Then, Mr. Beckerlee developed a performance monitoring system which can analyze vessel performance for each voyage based on noon reports; hereafter, in this thesis, this method will be referred to as the noon report method. Utilizing daily speed, fuel consumption, draft, and onboard wind and wave data from the noon reports, the vessel performance was normalized to a common reference draft in calm water to analyze each vessel on a per-voyage basis. AIS data was only used to verify validity of calculations, such as speed over ground. The performance monitoring system was developed for use by ship owners, charter managers, or ship operators to be able to compare a ship's performance to a charterparty standard. The previous thesis uses the same data set as this thesis with the same ships; however, more data has been added to the database since the previous thesis was finished.

In completing his thesis, Mr. Beckerlee has shown that it is possible to develop a performance monitoring system based on techniques from the ITTC 1978 performance prediction method and ISO speed and power trial analysis procedures, as these are well known, trusted, and widely used among naval architects [3]. He has also identified that the noon reports used contain a lot of faulty data. In these situations, using filters and common sense can improve the data quality significantly.

In the end, Mr. Beckerlee concluded that, once the effects of weather and draft were removed, the performance of the four MR tankers was comparable. However, for the limited number of voyages analyzed for the VLCCs, there appeared to be a significant difference in performance of the vessels. Mr. Beckerlee concluded that the VLCCs appear to have been operated in different methods leading to large differences in performance.

2 Automatic Identification System

This section describes the Automatic Identification System (AIS) installed onboard ships and summarizes the various ways that AIS data can be used to improve vessel performance analyses.

2.1 Shipboard Automatic Identification System

The Automatic Identification System (AIS) is a system installed on ships which regularly transmits identifying information and allows for tracking of the ship. The International Maritime Organization requires that all ships of 300 gross tons and larger on international voyages, cargo ships of 500 gross tons and larger not engaged on international voyages, and all passenger ships regardless of size be fitted with AIS transponders [21]. The AIS system on each ship integrates several pieces of navigation equipment to measure and automatically report key information including vessel identification, position, course, true heading, and speed over ground, amongst other data. AIS data are automatically transmitted from the vessel every few seconds while the vessel is underway. The data are also archived, which allows for viewing or analysis of a ship's voyage history.

2.2 Benefits of Using AIS Data in Vessel Performance Analysis

Although the AIS system is primarily used as a tracking and collision avoidance system, the high frequency of the transmitted information can be used to improve existing vessel performance analysis techniques. Many previous techniques rely on infrequent data logging, rely on human judgment for weather and wave conditions, and can be subject to data recording errors. Using the automatically recorded AIS data gives a much finer resolution of input data, allows for use of independent hindcast weather and wave data to reduce potential error, and allows for more detailed filtering of data. Because AIS data are publicly available and can be accessed by anyone who is interested, no additional sensors are needed onboard a ship to improve the accuracy of the performance analysis techniques.

2.2.1 Finer Resolution of Data

The first benefit of using AIS data is allowing for much finer data resolution in the performance analysis. Noon report data are very low resolution, typically having a sampling frequency of 24 hours, and this can lead to values being recorded which are not typical for the sampling period [5]. For example, the vessel speed through water changes constantly depending on power input and weather conditions. Furthermore, the wave and wind conditions can only be assumed to be statistically steady for a short period of time, between 30 minutes and 3 hours [23]. Only using one specific value for speed through water, wave height and direction, wind speed and direction, and any other constantly changing conditions during an entire 24 hour period will not capture the environmental changes that the ship will experience. As an example, Figure 2.1 shows a comparison of using hourly AIS versus daily noon report data for vessel speed. If the analysis only uses the daily speed through water recorded in the noon report, the calculations will miss the variation in speed through water seen in reality. Using input data with finer resolution allows for a much more precise performance analysis of the vessels.

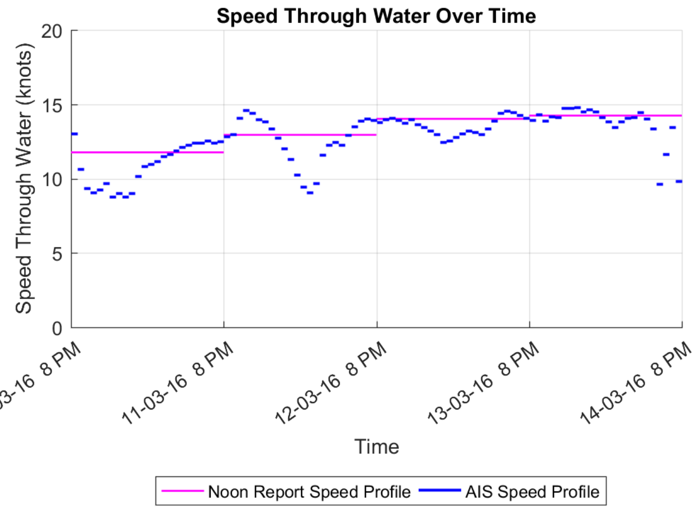


Figure 2.1: Speed Profile Comparison - Noon Report vs. AIS Data

2.2.2 Use of Independent Location and Hindcast Data

The second benefit of using AIS data is allowing for use of automatic ship location information and for use of hindcast data for ocean currents, wind conditions, wave conditions, and water properties for each voyage based on the hourly ship location. Using automatic ship location information and hindcast data can eliminate sources of error propagating from out-of-calibration onboard equipment, subjective measurements from personnel, and recording errors.

2.2.2.1 Speed Through Water

The speed through water of the ship is used throughout the calculations in the performance monitoring models. While speed over ground only takes into account the change in geographical position of the ship over time, speed through water also takes into account the speed of the ocean currents. It is important to use speed through water when calculating resistance instead of speed over ground. For example, if a ship is traveling at five knots through a seaway against a five knot current, the speed over ground would be zero, as the ship is not changing positions. However, it is obvious that the ship is using power to maintain the five knot forward speed, and thus has a speed through water of five knots.

The speed through water is typically measured onboard each vessel by means of the speed log. When calibrated correctly, the speed log can have accuracies up to 0.1% [13]. However, speed logs have been found to be unreliable. There are many environmental factors which can influence the accuracy of the speed log measurements, such as water clarity, aeration, ship's trim and list, current profile, eddy currents, sea state, and fouling of the sensor [13]. If the speed log is out of calibration, there can be an offset in the speed log measurements, as well.

If the speed log is used in the performance analysis, because the speed log calibration is different on every vessel, the comparison between performance of two sister ships may not be accurate. Instead, by using hindcast data, the speed through water can be calculated by combining the AIS speed over ground data, based on the Global Positioning System (GPS), with ocean currents from hindcast data. Using this process allows for a performance comparison of sister ships which is not affected by poor calibration of onboard equipment. The process of how the speed through water is calculated in the developed performance monitoring models is described in Section 5.1.

2.2.2.2 Wind, Waves, and Water Properties

The onboard measurements for the wave conditions recorded in the noon reports, such as wave height, period and propagating direction, are based on visual observations of the watchstander. However, it is notoriously difficult to judge wave conditions visually and can be very subjective based on the experience and ability of the watchstander. Therefore, the quality of the results is often questionable [17], and this can lead to errors in magnitude of the wave resistance calculation. Using hindcast data for wave height, period, and direction can eliminate any errors due to the objective observations of the crew.

The onboard measurements for the wind conditions recorded in the noon reports, such as wind speed and direction, are based on anemometer readings. However, the wind flow seen at each point on the ship is disturbed by the ship's own hull and superstructure [28]. Depending on the installed location of the anemometer on this ship, the effect of the disturbance on the wind measurements can vary. Using hindcast data for wind speed and direction can eliminate measurement error as a potential source of error.

The onboard measurements for water properties recorded in the noon reports only consists of water temperature. However, water density and viscosity are dependent on both temperature and salinity. Using hindcast data for water temperature and salinity allows for a more precise calculation of the water properties.

2.2.2.3 Recording Errors

Human error may occur when sampling or recording the data, potentially causing additional errors to be introduced into the analysis [5]. Mr. Beckerlee noted several cases of noon report recording errors in his analysis, which used an earlier version of the database used in this thesis. Often these errors relate to the ship's location, which then affect the speed and distance traveled calculations. An example of a recording error the ship's location is shown in Figure 2.2. In this example, the latitudinal position has been recorded as 3° North, when it should have been 3° South. These types of errors have to be fixed manually by the person analyzing the voyage. By using the automatically recorded AIS data based on the GPS coordinates, this source of error is eliminated.

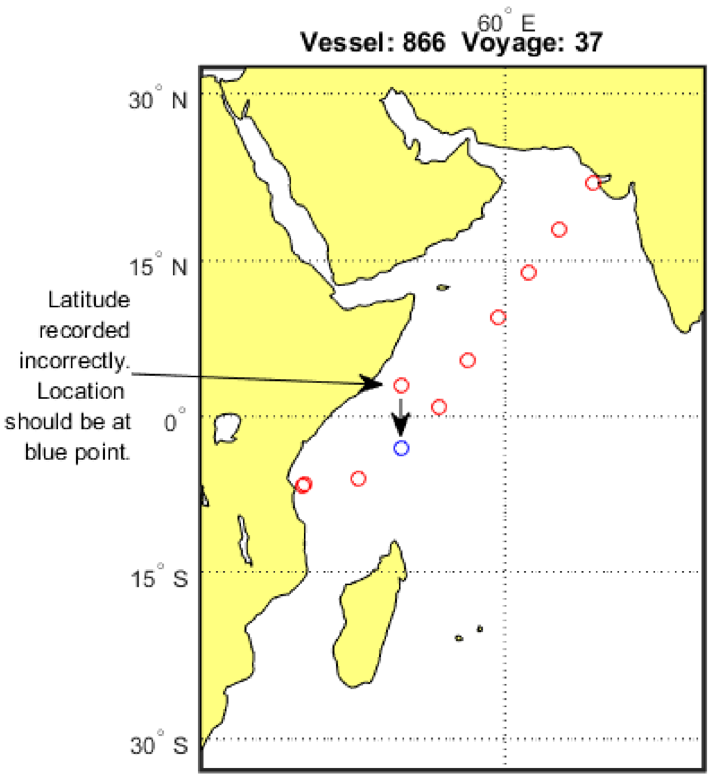


Figure 2.2: Example of Recording Error

2.2.3 Improved Filtering

The third benefit of using AIS data is to allow for precise filtering of the input data. The performance analysis techniques used in this thesis rely on resistance and propulsion model tests results conducted under steady state conditions and at a specified loading condition (draft). The model test results do not take into account unsteady forces, such as the hydrodynamic added mass experienced when a ship is accelerating or the induced resistance during turning maneuvers. The model test results also do not account for shallow or restricted water conditions. In all of these situations, the engine power used by the ship at a certain speed would be higher than in the normal condition. Filtering out the data points when these situations occur is necessary to ensure valid results.

The AIS data can be used to filter out the situations described above which would produce inaccurate results. Periods when the ship is accelerating and decelerating can be filtered out based on changes in the AIS reported speed. Periods when the ship is maneuvering can be filtered out based on changes in the AIS reported course or heading. Periods when the ship is not in the design laden condition can be filtered out based on the draft from the ship's loading computer. Additionally, there are periods when the ship is at anchor and not using fuel for propulsion and other periods when the AIS recordings are not available. These periods can be filtered out to improve the speed of the analysis program. All of these filters will improve the analysis and provide more accurate results.

The effect of using AIS data to filter the input data can be seen in Figure 2.3. In this example for Vessel 891, there are initially 5,342 data points which can be used to analyze the performance of the vessel. However, after all of the filters are applied, the number of data points is reduced to 1,839. This is a reduction of 65% of the number of points, which is a huge portion of the input data. It shows the importance of the being able to accurately filter out the situations which are not in the desired loading and steady state conditions.

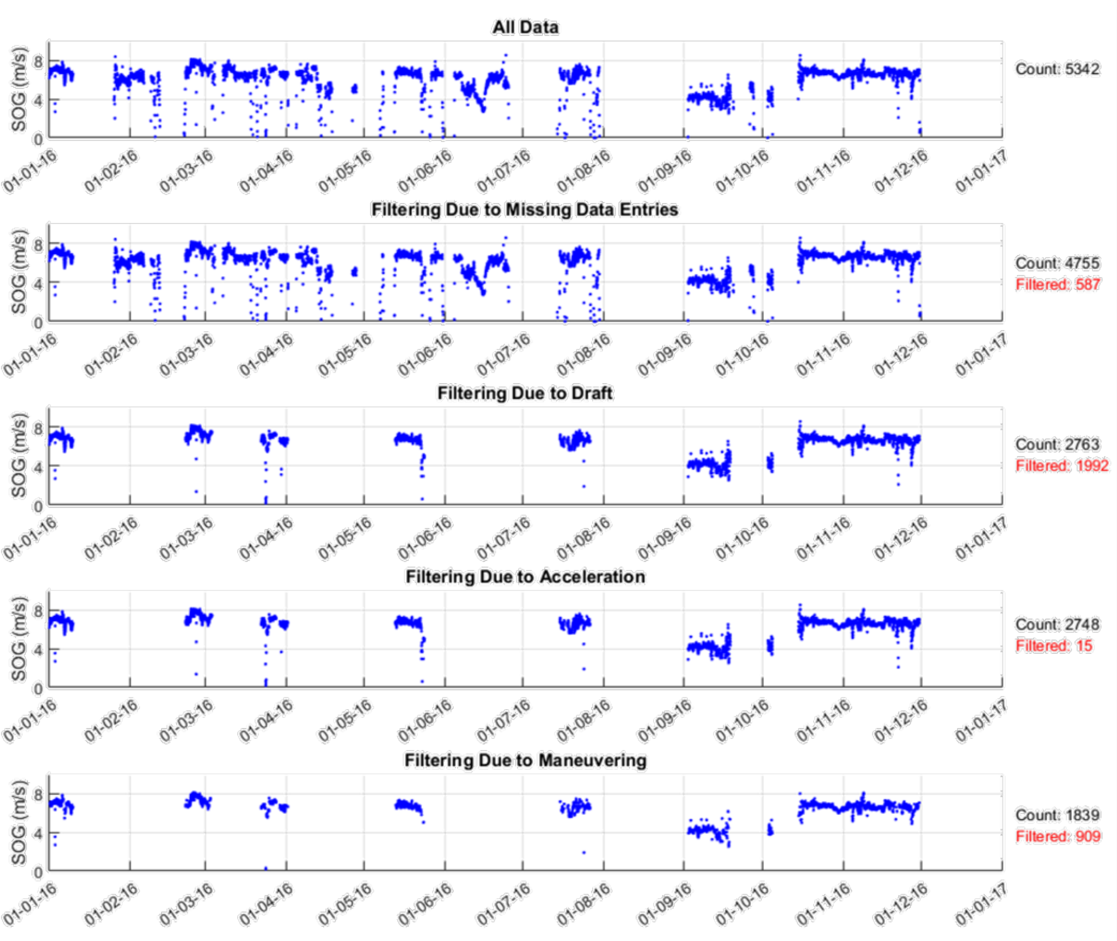


Figure 2.3: Example of AIS Data Filtering

3 Data

The ship data used in this thesis are provided by FORCE Technology. FORCE Technology is working with ship owners and is logging various data parameters for multiple ships. The data for the period between June 2015 and December 2016 has been compiled into a SQLite database, initially developed during Mr. Beckerlee's thesis [3]. In addition to the logged data, the database also includes ship-specific information such as ship specifications, model test results, and propeller open water curves. Separately, hindcast current, water property, wind, and wave information has also been acquired for use in the analysis. In this section, details of the data used in the analyses are discussed.

3.1 Ships

The database includes logged data for 11 ships of various types. These ships are identified by ship type and an anonymous vessel number to protect the identity of the ship owner and operator. However, although 11 ships are included in the database, certain key information is missing for some of the vessels, such as model test results. Therefore, only seven ships of two classes have been used in this analysis. These seven ships are described in Table 3.1.

Table 3.1: Vessel Information

Main Dimensions		
Vessel Type	**MR**	**VLCC**
Vessel Name	856, 858, 864, 866	885, 889, 891
Length	180 m	334 m
Breadth	32 m	58 m
DWT (Design)	50,000 tons	305,000 tons
C_B	0.79	0.81
Assumed Charterparty Values		
Min. Speed	13 knots	13 knots
Fuel Consumption	22.5 t/day	72 t/day

The database also contains various technical information for both of the ship classes above. The following technical information is included in the database:

- Condition of ships during model tests, including draft, hull surface area, displacement, tons per meter immersion, and frontal area.
- Effective Power (P_E) curve from the model tests.
- Delivered Power (P_D) curve from the model tests.

- Self-propulsion test results, including thrust deduction (t), wake fraction (w), relative-rotative efficiency (η_{RR}), and hull efficiency (η_H) values for each forward speed.
- Propeller information, including diameter, number of blades, and pitch.
- Propeller open-water curves, including thrust coefficient (K_T), torque coefficient (K_Q), and open water efficiency (η_0).
- Wind coefficients (C_X) of the ship for each relative wind direction.

3.2 AIS and Auto-Logged Data

The database includes over 120 fields of AIS and other automatically-logged data coming from the AIS system and other data acquisition systems onboard the vessels. However, the database does not include the raw data automatically reported through the AIS system every 30 seconds. Instead, the database includes statistical information for each of the reported fields for each period, typically approximately one hour in length. The fields from the AIS data used in this analysis are described in Table 3.2.

Table 3.2: AIS Data Fields

Field ID	**Field Description**
vessel_id	This field records the identification number of the vessel for the line of recorded data.
start	This field records the start time of the data logging. The time is recorded as Coordinated Universal Time (UTC). UTC is a time standard used worldwide and is not affected by time zone changes.
end	This field records the end time of the data logging in UTC.
lat_mean	This field records the average latitudinal position of the ship during the recording period.
lon_mean	This field records the average longitudinal position of the ship during the recording period.
sog_mean sog_min sog_max sog_std	This field records the average, minimum, maximum, and standard deviation of the speed over ground of the ship, calculated from the GPS positions or the GPS trip meter, during the recording period in meters per seconds.
hdt_mean hdt_min hdt_max hdt_std	This field records the average, minimum, maximum, and standard deviation of the true heading of the ship during the recording period in radians, where a heading of zero radians is equivalent to heading true north.

In addition to the AIS data, some additional auto-logged fields are used in this analysis when they are available. Those fields are described in Table 3.3.

Table 3.3: Auto-Logged Data Fields

Field ID	**Field Description**
srpm_mean	This field records the average shaft RPM of the ship during the recording period in revolutions per minute.
strq_mean	This field records the average shaft torque of the ship during the recording period in Newton-meters.

Unfortunately, sensors for these auto-logged fields are only available for one of the vessels analyzed: Vessel 891. This limits the detail that can be included in the voyage analysis of the other six vessels, which will be discussed further in Section 8.

3.3 Noon Report Data

In addition to the auto-logged data, the database also includes entries from the daily noon reports. The fields from the noon reports used in this analysis are described in Table 3.4.

3.4 Hindcast Data

Although the provided database includes fields for wind speed, wind direction, water temperature, wave direction, and sea state, this information is not used in the analysis. The auto-logged fields for wind speed and direction are only included for some of the periods and only for some of the vessels. The other fields are included once a day from the noon reports, and are based on visual observations. To compensate for the incomplete data and subjective observations, external hindcast weather data, calculated for shorter periods of time around the globe, is used in the analysis, as described in Section 2.2. This analysis makes use of hindcast data for ocean currents, water temperature and salinity, wind speed and direction, and wave speed, direction, and period.

3.4.1 Ocean Currents, Temperature, and Salinity

The ocean current, temperature, and salinity hindcast data comes from the 'Global Ocean 1/4° Physical Analysis and Forecast' data set accessed from Copernicus Marine Environment Monitoring Service [9]. This data set, modeled using the high resolution Met Office Global Seasonal Forecast System 5 (GloSea5), includes various parameters at 1/4-degree latitude and longitude intervals areas the globe on a daily-mean basis. This analysis makes use of sea water surface velocity in the northerly and easterly directions, sea water temperature at the surface, and sea water salinity at the surface.

Table 3.4: Noon Report Data Fields

Field ID	Field Description
report_start_utc	This field records the start time of the noon report in UTC.
report_end_utc	This field records the end time of the noon report in UTC.
main_engine_hfo_consumption	This field records the quantity of heavy fuel oil (HFO) consumed during the noon report period in tons.
main_engine_mdo_consumption	This field records the quantity of marine diesel oil (MDO) consumed during the noon report period in tons.
main_engine_mgo_consumption	This field records the quantity of marine gas oil (MGO) consumed during the noon report period in tons.
lower_calorific_value_for_hfo	This field records the lower calorific value of the HFO consumed during the noon report period in MJ/kg, if included. Else, a default value is used.
lower_calorific_value_for_mdo	This field records the lower calorific value of the MDO consumed during the noon report period in MJ/kg, if included. Else, a default value is used.
lower_calorific_value_for_mgo	This field records the lower calorific value of the MGO consumed during the noon report period in MJ/kg, if included. Else, a default value is used.
draught_fore	This field records the average draft of the ship at the bow during the noon report period.
draught_aft	This field records the average draft of the ship at the stern during the noon report period.
air_temperature	This field records the average air temperature during the noon report period in Celsius.
voyagename	The field records the name of the specific voyage.

3.4.2 Wind

The wind speed and direction hindcast data comes from the 'Global Ocean Wind L4 Near Real Time 6 Hourly Observations' data set accessed from the Copernicus Marine Environment Monitoring Service [8]. This data set, modeled by CERSAT (Centre ERS d'Archivage et de Traitement - *French ERS Processing and Archiving Facility*), includes wind parameters at 1/4-degree latitude and longitude areas for most of the globe on a 6-hour-mean basis. This analysis makes use of the northerly and easterly wind velocities at the water surface.

3.4.3 Waves

The wave height, direction, and period hindcast data comes from the the production data set developed by the National Oceanic and Atmospheric Administration (NOAA) using the Wavewatch III wave model [12]. This data set includes wave information at 1/2-degree latitude and longitude areas for most of the globe on a 3-hour basis. This analysis makes use of the significant wave height, wave direction, and wave period. Unfortunately, this data set does not include wave information for certain areas, such as the Red Sea and Panama Canal.

3.4.4 Note on Air Temperature Data

It is also possible to use hindcast data for air temperature; however, it was not done in this analysis due to practicality. Although the density of air is affected by temperature (in this analysis, as the calculations always occur at sea level, the variation of air density based on elevation is eliminated), the change in the ship's air resistance due to the change in air temperature is relatively small compared to other resistance components. Therefore, instead of acquiring the large hindcast data set required for air temperature, the daily air temperature recorded in the noon reports were used for each corresponding analysis period.

4 Ship Performance Parameters

This section provides basic information regarding the main parameters of ship resistance and propulsion which are analyzed in this thesis.

4.1 Ship Resistance

The resistance of the ship traveling through water is made up of many components. It can be split up into components calculated in a static environment, such as hull resistance, and components due to a dynamic environment, such as the presence of wind and waves. The main components of resistance studied in this analysis are described below.

4.1.1 Hull Resistance

As a ship's hull passes through a body of water, it experiences resistance to its forward motion. The ship's hull resistance is mainly composed of two components: resistance due to wave making, and resistance due to friction [16]. Resistance due to wave making takes into account displacement of water and the waves generated by the ship hull when traveling through a still body of water. Frictional resistance takes into account the resistance due to the hull dragging water along with it, due to the boundary layer. The area of the hull and deckhouse above the water line also experience air resistance when traveling at a forward speed.

The wave making resistance and air resistance for a certain loading condition are not expected to change over time, as the hull and deckhouse shape are expected to remain constant over the analyzed period. However, the frictional resistance will change. The frictional resistance of a ship is proportional to the roughness of the hull, which increases as the hull becomes fouled over time. As the hull becomes fouled and the frictional resistance increases, the performance of the ship will degrade.

4.1.2 Added Wave Resistance

As a ship passes through sea waves, it experiences added resistance due to two wave systems: the reflection of short waves on the hull, and the wave-induced heave and pitch motions of the ship [4]. The magnitude of added resistance is dependent on a number of factors, including ship particulars, such as length, beam, and speed, as well as wave parameters, such as significant wave height, wave period, and wave direction. Therefore, the magnitude of added wave resistance will change constantly over the life of the ship. To be able to compare a ship's performance over time, the added resistance due to waves has to be removed from the total resistance, depending on the wave conditions experienced at each specific location and time.

4.1.3 Added Wind Resistance

Although the resistance of the ship's hull in water is the dominant part of the total resistance, there is also added resistance due to the movement of air. Even though the resistance estimates from the model tests take into account air resistance in still air, there can be added resistance due to wind. The added resistance due to wind is dependent on ship particulars, such as drag coefficients and frontal area, and wind parameters, such as speed and direction. In situations where the wind comes from behind the ship, the added resistance can become negative, lowering the total resistance of the ship. Similar to added wave resistance, the added wind resistance will also constantly change over time, and will have to be removed from the total resistance experienced at each specific location and time to be able to compare a ship's performance over time.

4.1.4 Change in Resistance Due to Draft

The resistance of a ship's hull changes depending on the loading condition of the ship. A ship with a greater draft will have greater wave making resistance, as the ship will have to displace more water and generate different waves when traveling at forward speed, as well as greater frictional resistance due to the larger surface area of the hull.

The operating draft of the ship is expected to change regularly throughout the life of the ship. The draft will likely change for each new voyage, as the cargo load may be different from voyage to voyage, or the ship may travel in ballast condition (unloaded). Furthermore, within a specific voyage, the draft will change due to the burning of the fuel. To be able to accurately compare the ship's performance across multiple journeys with different drafts, a correction has to be applied to normalize the resistance to the design condition.

4.1.5 Change in Resistance Due to Water Properties

The resistance of a ship is dependent on the properties of the water in which it is traveling. The hull resistance is proportional to the density and viscosity of water. Water with a higher density and higher viscosity will in turn increase the resistance of the ship. The sea water density and viscosity are dependent on the temperature and salinity of the water, which vary depending on body of water, location, and time of year. To be able to accurately compare the ship's performance across multiple journeys, a resistance correction has to be applied to adjust the resistance to a normalized water condition.

4.2 Ship Powering

For the ships studied in this thesis, propulsion power from the engine is transmitted to the surrounding water by way of a propeller. The performance of the propeller is not only dependent on the design of the propeller, but is also highly dependent on the flow into the propeller field. Some of the values meant to describe the flow into the propeller, such as the wake fraction coefficient, thrust deduction coefficient, hull efficiency, and relative-rotative efficiency, are calculated during model testing. The propeller performance itself, described by nondimensional thrust and torque coefficients, is determined during open water model tests.

4.2.1 Effective Power

The effective power (P_E) of the ship is the ideal amount of power needed to propel the ship through the water at a certain speed, assuming that 100% of the power developed by the engine is transmitted to the water. The effective power can be calculated as shown in Equation 4.1.

$$P_E = R \cdot V \tag{4.1}$$

where:

P_E is the effective power of the ship
R is the resistance experienced by the ship
V is the velocity of the ship

4.2.2 Wake Fraction Coefficient

As the ship moves through water with a forward speed, a boundary layer of water is formed around the hull. Within this boundary layer, the speed of the water is reduced due to friction. The thickness of the boundary layer increases along the length of the hull and is largest at the stern, near the location of the propeller. The propeller will usually be in operating within this area of slower water, also known as the wake field. The wake fraction coefficient (w) is a method of describing the effect of this boundary layer on the speed of the water at the propeller inlet.

4.2.3 Thrust Deduction

As the propeller rotates and provides forward thrust, it speeds up the flow of the water coming into the propeller field. The increased speed of the flow results in an increase in hull resistance due to the increase in frictional forces. As this increase in resistance is only seen when thrust is being applied, a thrust deduction factor (t) is used when determining the required forward thrust.

4.2.4 Hull Efficiency

The hull efficiency (η_H) is the ratio of the effective power and thrust power, and can be calculated as shown in Equation 4.2.

$$\eta_H = \frac{1-t}{1-w} \tag{4.2}$$

where:

η_H is the hull efficiency
t is the thrust deduction factor
w is the wake fraction coefficient

4.2.5 Propeller Open Water Curves

Propeller open water characteristics, determined during the open water tests, are typically given in terms of the nondimensional thrust coefficient (K_T), nondimensional torque coefficient (K_Q), and open water efficiency (η_0) for each advance ratio (J). By using nondimensional coefficients and the advance ratio, the performance of a certain diameter propeller can be calculated when operating behind different ships, at various ship speeds, and at various revolutions.

4.2.6 Relative Rotative Efficiency

When operating in open water, the inflow into a propeller will be irrotational as there is nothing affecting the flow pattern into the propeller. However, in reality, due to the presence of the hull in front of the propeller, the inflow into the propeller will have some rotation. The relative rotative efficiency (η_{RR}) is a measure of the change of efficiency of the propeller due to the rotational flow.

4.2.7 Delivered Power and Fuel Consumption

Delivered power (P_D), also known as shaft power, is a measure of the power required to be delivered to the propeller to achieve the desired forward speed, taking into account the losses due to the shafting, propeller, hull design, and hull condition. Over time, as the resistance of the ship increases, the necessary power to achieve a certain speed will also increase. The delivered power can be calculated as shown in Equation 4.3.

$$P_D = \frac{P_E}{\eta_H \eta_0 \eta_{RR}} \tag{4.3}$$

where:

P_D is the delivered power of the ship
P_E is the effective power of the ship
η_H is the hull efficiency
η_0 is the propeller open water efficiency
η_{RR} is the relative rotative efficiency

The fuel consumption of a ship is directly proportional to the required delivered power. Therefore, an increase in necessary power will also lead to an increase in fuel consumption. The fuel consumption is also dependent on the specific fuel oil consumption of the engine and the efficiency of the transmission and shafting system. However, in this analysis, both the specific fuel oil consumption of the main engine ($SFOC_{ME}$) and the transmission efficiency (η_{trans}) are assumed to remain constant over time, taken as 0.175 kg/kWh and 98% respectively [3].

5 Speed Through Water

This section presents a description and validation of the method to calculate speed through water in the performance analysis models.

5.1 Calculation

The speed through water (STW) is typically measured onboard each vessel by means of the speed log. However, as described in Section 2.2.2.1, speed logs have been found to be unreliable. The speed log measurements are affected by many environmental factors, and poor calibration can lead to additional errors in the measurements. Therefore, instead of relying on the vessels' speed logs, this analysis combines speed over ground (SOG) data with hindcast data to calculate the speed through water. The speed over ground data are auto-logged based on the Global Positioning System (GPS) of each vessel and therefore not subject to the same measurement errors as the speed log. The ocean current northward and eastward velocities, from which the overall current velocity and direction can be calculated, are retrieved from the hindcast data based on the position and time from the AIS period. The speed through water is then calculated as shown in Equation 5.1.

$$\begin{aligned} SOC_{\chi} &= (SOC) \cdot cos(\chi - \chi_C) \\ STW &= SOG + SOC_{\chi} \end{aligned} \tag{5.1}$$

where:

SOC is the total speed of the ocean currents
χ is the heading of the ship
χ_C is the direction of the ocean currents
SOC_{χ} is the speed of the ocean currents in the direction of travel
SOG is the speed over ground of the ship
STW is the speed through water of the ship

5.2 Validation

To see the benefit of using hindcast data versus the speed log to determine the speed through water of the ships, a comparison of the two methods was performed. The speed through water measured from the onboard speed log was plotted against the speed through water calculated from the speed over ground and hindcast ocean current data, allowing a visual comparison of measurements. Ideally, if the speed log was calibrated and the hindcast data was perfectly accurate for the location and time of the ship, both measurements would be identical. Visualizations of these comparisons are shown in Figure 5.1. For clarity purposes, only small sections of each comparison are shown. However, unless otherwise noted, the trends remain the same throughout the analysis period.

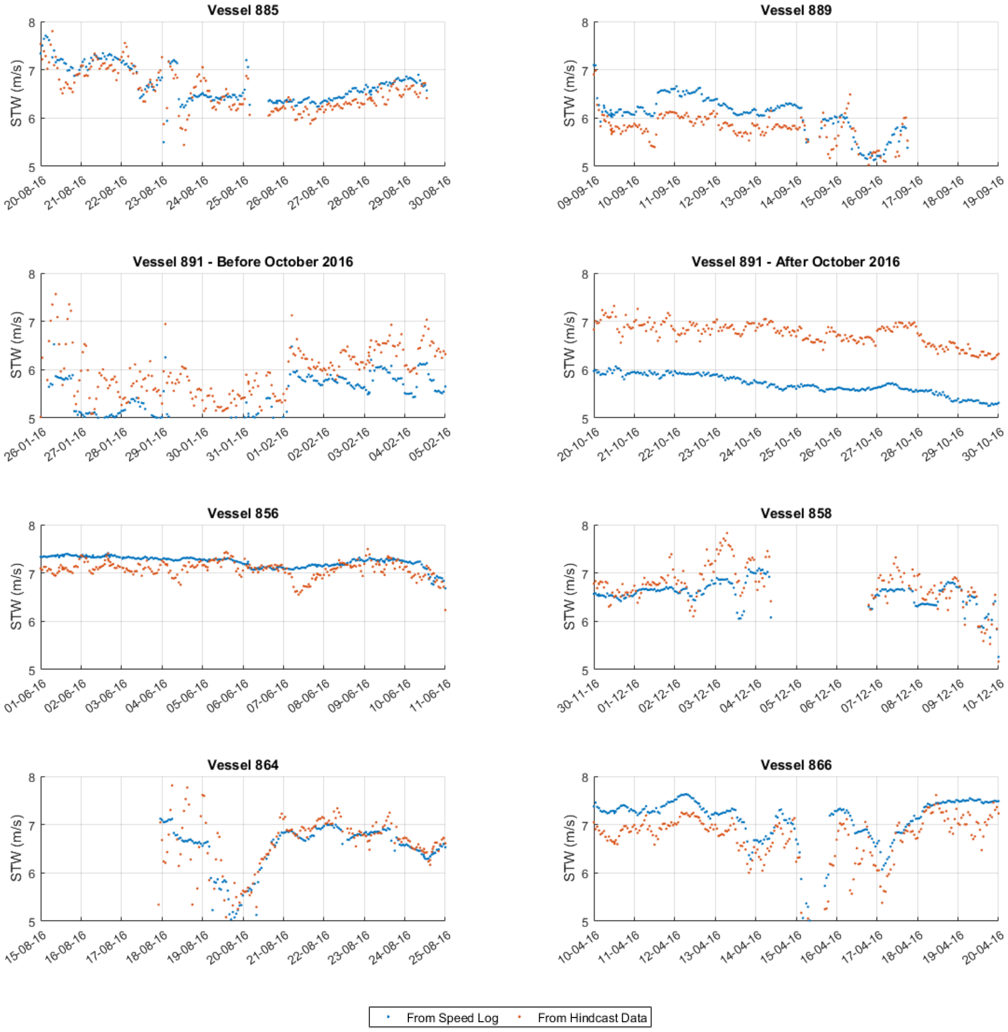


Figure 5.1: Speed Through Water Comparison

The comparisons between the two methods of calculating speed through water yield positive results. In general, both methods of calculating speed through water yield speed through water measurements which follow the same trends; that is, for many of the AIS periods, the difference between speed log measurements and the calculated speed through water tend to be fairly constant. However, it is clearly obvious that some ships have a difference in magnitude between the two measurements. An approximate magnitude of this difference is shown in Table 5.1. While most of the vessels have speed logs which typically read within ± 0.3 m/s from the calculated speed through water, Vessel 891 has measurements as far off as 1.0 m/s. The differences in the measurements is most likely due to poor calibration of the speed log.

Table 5.1: Speed Through Water Measurement Difference

Vessel	**Speed Log Measurement**
885	+0.2 m/s
889	+0.5 m/s
891 (Before 10/16)	-0.5 m/s
891 (After 10/16)	-1.0 m/s
856	+0.2 m/s
858	-0.1 m/s
864	~0.0 m/s
866	+0.3 m/s

By calculating speed through water using the GPS-based speed over ground combined with the hindcast data for ocean currents, the errors in measurements due to poorly calibrated speed logs are eliminated. However, the coarseness of the hindcast data used in this analysis introduces different errors. The data set used has a resolution of 1/4-degree, which depending on the latitude, yields a minimum area of approximately 25 kilometers by 25 kilometers. Furthermore, the data set used only has the daily mean value for ocean currents. Currents, especially when closer to coastlines, can vary significantly depending on location and can also change many times throughout the day, which is not captured by using the hindcast data set. The propagation of this error can also be seen in the speed through water plots in Figure 5.1, repeated as an example for Vessel 856 in Figure 5.2. At times when the speed through water measured by the speed log remains smooth and relatively constant, there is often additional scatter in the speed through water calculated using the hindcast data. This error can be reduced by using finer hindcast data; however, it was not possible to acquire finer data for use in this thesis. Still, the benefit of using hindcast data to eliminate the speed log calibration error outweighs the minor scatter introduced into speed through water measurements. Therefore, it was decided to continue the analysis using the speed through water measurements calculated using the hindcast data.

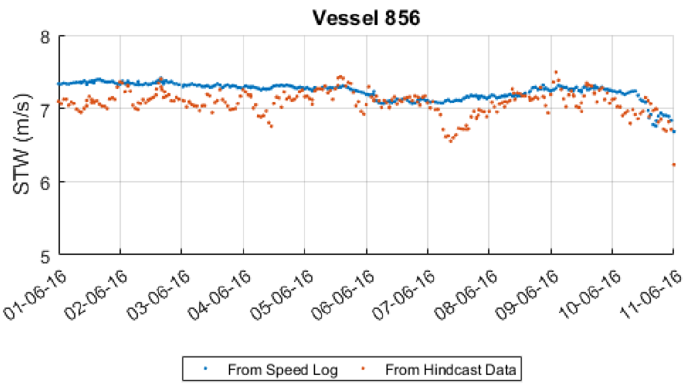


Figure 5.2: Speed Through Water Comparison - Vessel 856

6 Model 1 Description - Per Noon Report

This section describes the first performance analysis model developed in this thesis. This model, which analyzes the vessel performance on a per-noon-report basis, can be used for all vessels for which daily fuel consumption values are available.

6.1 Model Description

The first model that has been developed for this thesis, hereafter referred to as Model 1, uses minimal data from the noon reports to eliminate as many potential sources of error as possible. Model 1 only uses the report start time, report end time, fuel consumption, fuel properties, draft, and air temperature from the noon reports. The rest of the calculations use the AIS data or information determined using the geographical location and time of the AIS data. Ideally, the ship drafts would be auto-logged from the onboard loading computers and the air temperature would be determined from hindcast data, further reducing the reliance on noon reports. However, data from the loading computers was not available for this thesis, and air temperature data was not retrieved from hindcast data for practicality as discussed in Section 3.4.4. A flowchart showing where the data used in Model 1 are retrieved from and how they are used is shown in Figure 6.1.

The implementation of Model 1 in MATLAB follows the process below:

1. Filter data points to eliminate times when the ship is not in the desired condition.
2. Determine the speed through water of the ship by adding the ocean currents in the direction of travel at the specified location and time to the AIS speed over ground values.
3. Determine the density, salinity, and viscosity of the water at the specified location and time from the hindcast data.
4. Determine the significant wave height, wave direction, and wave period of the seas at the specified location and time from the hindcast data.
5. Determine the wind speed and direction at the specified location and time from the hindcast data.
6. Calculate the measured resistance of the ship by converting the fuel consumption to power and then to resistance.
7. Determine the corrections to ship resistance due to the water properties, waves, wind, and draft, and correct the resistance based on these calculations.
8. Calculate the corrected delivered power and then a fuel index to determine the performance level of the ship over time and to allow for a comparison of performance of multiple ships to each other.

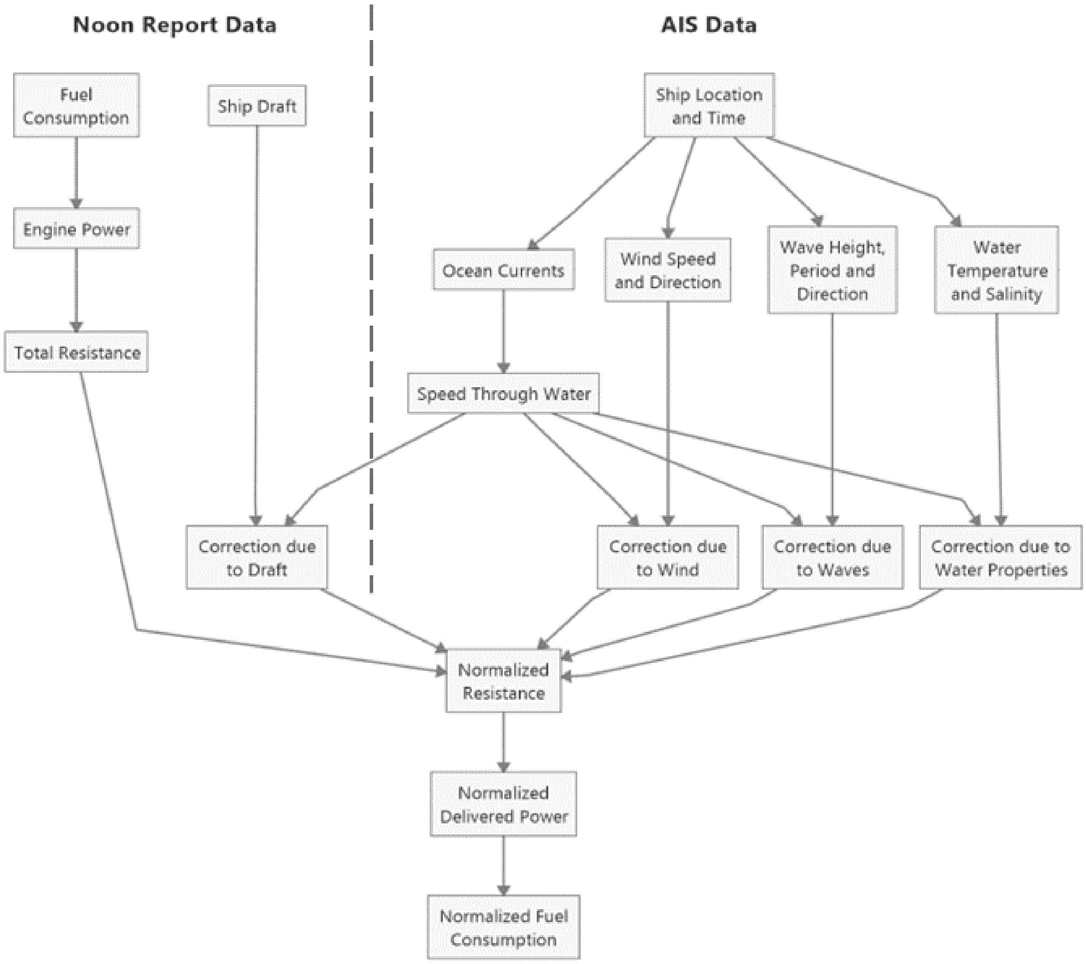


Figure 6.1: Model 1 Flowchart

As the fuel consumption data from the noon reports is only available once per noon report, Model 1 analyzes the resistance and fuel consumption performance of the ship on a per-noon-report basis. The corrections for each of the additional resistance components are calculated for each AIS period (typically one hour), and the sum of these corrections is applied over the entire noon report period. The key steps of the process are described in more detail in the following subsections.

6.2 Assumptions

Model 1 was developed with the assumption that the decrease in performance is solely due to hull and propeller fouling. The model does not take into account any degradation of engine or transmission performance due to wear or poor maintenance.

Tests conducted on ship models and full scale ships have shown that the thrust deduction factor remains nearly constant over time, independent of the condition of the hull [15]. Similarly, the relative rotative efficiency of a ship can be assumed to remain unchanged over time [15]. Therefore, in this analysis, the thrust deduction factors and relative rotative efficiencies measured during the self-propulsion tests are used throughout the analysis.

As the hull becomes rougher or fouled, the flow around the hull is affected. The decrease in hull performance can be represented by an increase in wake fraction. However, without knowing the condition of the hull or the propeller revolutions at the time of the analysis, there are no methods of calculating in-service wake fraction coefficients. Additionally, due to the use of anti-fouling hull paints and improved hull maintenance (regular cleanings are cited for most vessels in this analysis), the hull condition is expected to deteriorate relatively slowly [19]. Therefore, in Model 1, the wake fraction coefficients measured during the self-propulsion tests are used throughout the analysis, irrespective of time.

As the thrust deduction factors and wake fraction coefficients are taken as remaining constant through this model, the hull efficiency values will also remain constant throughout the model.

6.3 Filtering

The input data for each voyage is filtered using both static and dynamic filters. The static filters ensure that the program only analyzes the situations when the ship is in the desired loading and when there is valid AIS data covering the entire noon report. The dynamic filters ensure that the ship is in a steady state condition. Filtering in Model 1 occurs based on six factors:

Static Filters:

1. Any AIS periods which are missing the required data fields described in Tables 3.2 and 3.4 are removed, as the analysis cannot be completed without complete information.
2. Any periods during which the ship is operating at a draft significantly different from the design loading condition, taken as ± 2 meters in this analysis, are removed.
3. As the analysis is based on the fuel consumption over an entire noon report period, the AIS data also needs to cover the same period of time. Any noon reports for which there is not complete AIS data are not analyzed.
4. Any noon reports for which there appears to be incorrect fuel use information or for which the speed over ground is negligible (indicating the ship is at anchor) are removed manually by the user.

Dynamic Filters:

5. Any periods during which the ship is accelerating or decelerating are removed, taken as when the standard deviation of the speed over ground measurements is greater than 0.10. As the raw data and thus the actual distribution of speeds are not available, it is impossible to know the statistical confidence level determined by this level of standard deviation. However, the goal of choosing this standard deviation level is not to remove all points when there is a small change in speed or when the change in speed occurs over a short period of time relative to the noon report length. As the vessels are subject to random seas and always experience some lateral acceleration, filtering out all points with changes in speed would inevitably eliminate almost all data points in the analysis. These cases of small lateral accelerations do not significantly affecting the total fuel consumption calculation over an entire noon report period, and thus should not be filtered out. Instead, the standard deviation level was chosen to eliminate the times when the largest changes in speeds and when prolonged periods of acceleration appears to occur.

6. Any periods during which the ship is maneuvering are removed, taken as when the standard deviation of the heading measurements is greater than 0.10, using the same reasoning as for the acceleration filter described above.

6.4 Speed Through Water

The speed through water (STW) for each period is calculated as described in Section 5.1.

6.5 Water Properties

Properties of seawater vary depending on location and time of year. Specifically, the density and viscosity of seawater are variable on different factors, such as temperature and salinity. The temperature and salinity are retrieved from the hindcast data at the specified location and time of the AIS period. Then, both the water density and dynamic viscosity can be calculated based on correlation equations. The seawater density and viscosity can be calculated for each AIS period using the correlation equations in Appendix A.

6.6 Measured Ship Resistance

The measured ship resistance is calculated based on the amount of total work done by the ship over the course of one noon report. By using the known amount of fuel burned over a known distance, the total amount of energy consumed by the engine can be calculated. However, the specific fuel oil consumption of the main engine is based on a standard fuel oil with a Lower Calorific Value (LCV) of 42.7 MJ/kg. Therefore, a standardized total amount of fuel burned has to be calculated before calculating the work done by the engine, as shown in Equation 6.1.

$$M_{fuel} = M_{HFO}\frac{LCV_{HFO}}{LCV_{ISO}} + M_{MDO}\frac{LCV_{MDO}}{LCV_{ISO}} + M_{MGO}\frac{LCV_{MGO}}{LCV_{ISO}} \tag{6.1}$$

where:

M_{fuel} is the total fuel consumption by the ship over the noon report period
M_{HFO} is the heavy fuel oil (HFO) consumption by the ship over the noon report period
M_{MDO} is the marine diesel oil (MDO) consumption by the ship over the noon report period
M_{MGO} is the marine gas oil (MGO) consumption by the ship over the noon report period
LCV_{ISO} is the ISO standard LCV, taken as 42.7 MJ/kg
LCV_{HFO} is the measured LCV of the HFO used
LCV_{MDO} is the measured LCV of the MDO used
LCV_{MGO} is the measured LCV of the MGO used

If the measured LCVs of the fuel oils are not included in the database, the LCVs listed in Table 6.1 are assumed [3].

Table 6.1: Assumed Lower Calorific Values if Unspecified

Fuel Type	**Assumed LCV**
HFO	40.3 MJ/kg
MDO	42.2 MJ/kg
MGO	42.2 MJ/kg

Once the standardized fuel consumption has been calculated, the total energy consumed by the engine, and therefore work delivered to the propeller, can be calculated, as shown in Equation 6.2.

$$W_D = \frac{M_{fuel} \cdot \eta_{trans}}{SFOC_{ME}} \tag{6.2}$$

where:

W_D is the total work delivered by the engine over the noon report period
M_{fuel} is the total fuel consumption by the ship over the noon report period
η_{trans} is the efficiency of the transmission
$SFOC_{ME}$ is the specific fuel oil consumption of the main engine

The effective work of the ship can then be calculated by multiplying the work delivered by the engine by the hull, relative-rotative, and open water efficiencies, as shown in

Equation 6.3. Because the ship speed changes at each AIS period within the noon report period, a weighted average of the efficiencies is used.

$$W_E = W_D \frac{\sum_{i=1}^{n} \eta_{h,i} \cdot \eta_{RR,i} \cdot \eta_{0,i} \cdot d_i}{\sum_{i=1}^{n} d_i} \tag{6.3}$$

where:

W_E is the effective work done by the ship over the noon report period

W_D is the work delivered by the ship over the noon report period

η_H is the hull efficiency for each AIS period, calculated as shown in Equation 4.2

η_{RR} is the relative-rotative efficiency for each AIS period

η_0 is the open water efficiency for each AIS period

d_i is the distance traveled for each AIS period

6.7 Correction Due to Waves

The correction to ship resistance due to waves is calculated using the STAWAVE-2 empirical correction method. This method approximates a transfer function for the mean added resistance in head waves using key parameters such as ship dimensions and speed [27]. This transfer function covers both the added resistance due to wave reflection and due to motion. By combining this transfer function with the wave spectrum, the added resistance of the ship in a certain wave condition can be calculated. Model testing using a containership and a tanker have shown that the STAWAVE-2 method for predicting added resistance is more reliable than other existing empirical methods [4]. However, the method is still limited to predicting added resistance from head seas, with relative wave directions up to ±45 degrees off the bow. Waves with a relative direction outside of this arc are not corrected in this analysis.

The STAWAVE-2 empirical transfer function for mean added resistance due to induced motion (R_{AWML}) and wave reflection (R_{AWRL}) is calculated by summing the two components together, as shown in Equation 6.4 [27].

$$R_{wave} = R_{AWML} + R_{AWRL} \tag{6.4}$$

The mean added resistance due to induced motion from waves (R_{AWML}) is calculated as shown in Equation 6.5 [27].

$$R_{AWML} = 4\rho_w g \zeta_A^2 \frac{B^2}{L_{PP}} \overline{r_{aw}}(\omega) \tag{6.5}$$

with:

$$\begin{aligned}
\overline{r_{aw}}(\omega) &= \bar{\omega}^{b_1} \exp\left\{\frac{b_1}{d_1}\left(1-\bar{\omega}^{d_1}\right)\right\} a_1 Fr^{1.50} \exp\left(-3.50 Fr\right) \\
\bar{\omega} &= \frac{\sqrt{\frac{L_{PP}}{g}}\sqrt[3]{k_{yy}}}{1.17 Fr^{-0.143}}\omega \\
a_1 &= 60.3 C_B^{1.34} \\
b_1 &= \begin{cases} 11.0 & \text{for } \bar{\omega} < 1 \\ -8.50 & \text{elsewhere} \end{cases} \\
d_1 &= \begin{cases} 14.0 & \text{for } \bar{\omega} < 1 \\ -566\left(\frac{L_{PP}}{B}\right)^{2.66} & \text{elsewhere} \end{cases}
\end{aligned}$$

where:

- ρ_w is the water density experienced in kg/m^3
- g is the acceleration of gravity, taken as 9.81 m/s^2
- ζ_A is the wave amplitude in meters
- L_{PP} is the ship's length between perpendiculars in meters
- B is the ship's breadth in meters
- C_B is the ship's block coefficient
- Fr is the Froude number corresponding to the ship's STW
- k_{yy} is the ship's non-dimensional radius of gyration in the lateral direction, assumed to be 0.25L [24]

The mean added resistance due to wave reflection (R_{AWRL}) is calculated as shown in Equation 6.6 [27].

$$R_{AWRL} = \frac{1}{2}\rho_w g \zeta_A^2 B \alpha_1(\omega) \tag{6.6}$$

with:

$$\alpha_1 = \frac{\pi^2 I_1^2(1.5kT_M)}{\pi^2 I_1^2(1.5kT_M) + K_1^2(1.5kT_M)} f_1$$
$$f_1 = 0.692\left(\frac{STW}{\sqrt{T_M g}}\right)^{0.769} + 1.81C_B^{6.95}$$

where:

ρ_w is the water density experienced in kg/m^3
g is the acceleration of gravity, taken as 9.81 m/s^2
ζ_A is the wave amplitude in meters
B is the ship's breadth in meters
T_M is the ship's draft in meters
C_B is the ship's block coefficient
STW is the ship's speed through water in m/s
I_1 is the modified Bessel function of the first kind of order 1
K_1 is the modified Bessel function of the second kind of order 1
k is the wave number of the current sea conditions in rad/m

The mean added resistance due to waves is then evaluated as shown in Equation 6.7 [27].

$$R_{AWL} = 2\int_0^\infty \frac{R_{wave}(\omega; STW)}{\zeta_A^2} S_\eta(\omega)d\omega \tag{6.7}$$

where:

R_{AWL} is the mean resistance increase in long crested irregular waves in Newtons
R_{wave} is the mean resistance increase in regular waves in Newtons, calculated in Equation 6.4
ζ_A is the wave amplitude in meters
ω is the circular frequency of regular waves in rad/s
C_B is the ship's block coefficient
STW is the ship's speed through water in m/s
S_η is the wave frequency spectrum in m^2/s

For practicality in this thesis, the wave frequency spectrum was assumed to follow the Bretschneider wave spectrum independent of location. The Bretschneider spectrum is typically used for fully developed seas usually found in open ocean environments, and can be calculated as shown in Equation 6.8 [20].

$$S_\eta(\omega) = \frac{A}{\omega^5} \exp\left(\frac{-B}{\omega^4}\right) \tag{6.8}$$

with:

$$A = \frac{H_s^2}{4\pi}\left(\frac{2\pi}{T_z}\right)^4$$
$$B = \frac{1}{\pi}\left(\frac{2\pi}{T_z}\right)^4$$
$$T_Z = \frac{1.296}{1.41} \cdot T_W$$

where:

$S_\eta(\omega)$ is the wave frequency spectrum in m^2/s
ω is the circular frequency of regular waves in rad/s
H_s is the significant wave height in meters
T_W is the wave period in seconds

6.8 Correction Due to Wind

The correction to ship resistance due to wind is based on the Bernoulli equation and a directional drag coefficient. The directional drag coefficients, provided in the database from FORCE Technology, are based upon wind tunnel model tests of a similar vessel [1]. The added resistance due to wind can then be calculated as shown in Equation 6.9 [26].

$$R_{wind} = \frac{1}{2}\rho_{air} V_{air}^2 C_X A_F \tag{6.9}$$

where:

R_{wind} is the wind force in Newtons
ρ_{air} is the density of air at the experienced air temperature in $\mathrm{kg/m}^3$
V_{air} is the wind speed in m/s
C_X is the wind coefficient for the relative wind direction
A_F is the ship's above water frontal area in m^2

6.9 Correction Due to Draft

The correction for resistance due to differences in draft is based on the International Organization for Standardization (ISO) guidelines for analysis of speed trial data. The correction is meant to be used to correct small changes in draft (2% difference in ship displacement); however, in this analysis, it is applied for draft changes of

±2 meters to increase the availability of data points analyzed. The correction to resistance due to change in draft is shown in Equation 6.10 [26].

$$R_{ADIS} = 0.65 R_T \left(\frac{\Delta_0}{\Delta} - 1 \right) \tag{6.10}$$

where:

R_{ADIS} is the additional resistance due to an increase in draft in Newtons
R_T is the total resistance in the design condition in Newtons
Δ_0 is the displacement in the design condition
Δ is the displacement in the analyzed condition

6.10 Correction Due to Water Properties

The resistance correction due to water properties is based on the ISO guidelines for analysis of speed trial data. The correction to resistance due to differences in water temperature and salt content, and thus due to differences in water density and viscosity, is shown in Equation 6.11 [26].

$$R_{AS} = R_T \left(1 - \frac{\rho_w}{\rho_{w0}} \right) - R_F \left(1 - \frac{C_{F0}}{C_F} \right) \tag{6.11}$$

where:

R_{AS} is the resistance correction due to change in water properties in Newtons
R_T is the total resistance at the standard water properties from the model tests in Newtons
R_F is the frictional resistance in the experienced water conditions in Newtons
C_{F0} is the frictional resistance coefficient in standard water conditions
C_F is the frictional resistance coefficient in the experienced water conditions
ρ_w is the water density in the experienced water conditions in kg/m^3
ρ_{w0} is the water density in the standard water conditions in kg/m^3

6.11 Corrected Resistance

The corrected resistance of the ship over each noon report period can be calculated by subtracting the work done by corrections (resistance correction times distance traveled during each AIS period) from the total effective work done by the ship, and then dividing by the total distance traveled, as shown in Equation 6.12.

$$R_{corrected} = \frac{W_E - \sum_{i=1}^{n} R_{AWL,i} \cdot d_i - \sum_{i=1}^{n} R_{wind,i} \cdot d_i - \sum_{i=1}^{n} R_{ADIS,i} \cdot d_i - \sum_{i=1}^{n} R_{AS,i} \cdot d_i}{\sum_{i=1}^{n} d_i} \tag{6.12}$$

where:

$R_{corrected}$ is the mean corrected resistance over the noon report period in Newtons
W_E is the effective work done by the ship, calculated in Equation 6.3
$R_{AWL,i}$ is the resistance correction due to waves, calculated in Equation 6.7
$R_{wind,i}$ is the resistance correction due to wind, calculated in Equation 6.9
$R_{ADIS,i}$ is the resistance correction due to draft, calculated in Equation 6.10
$R_{AS,i}$ is the resistance correction due to water properties, calculated in Equation 6.11
d_i is the distance traveled for each AIS period

6.12 Delivered Power

The power delivered to the propeller can be calculated based on the corrected resistance and other ship parameters. As the ship's speed changes multiple times per day, the speed through water and efficiencies are taken as weighted averages over the noon report period, as shown in Equation 6.13.

$$P_{D,corrected} = \frac{R_{corrected} \cdot \left(\frac{\sum_{i=1}^{n} STW_i \cdot d_i}{\sum_{i=1}^{n} d_i} \right)}{\left(\frac{\sum_{i=1}^{n} \eta_{H,i}\eta_{0,i}\eta_{RR,i} \cdot d_i}{\sum_{i=1}^{n} d_i} \right)} \tag{6.13}$$

where:

$P_{D,corrected}$ is the normalized delivered power over the noon report period in Watts
$R_{corrected}$ is the corrected resistance in Newtons for the noon report period, calculated in Equation 6.12
STW_i is the ship's speed through water for each AIS period in m/s
η_H is the hull efficiency for each AIS period
η_0 is the propeller open water efficiency for each AIS period
η_{RR} is the relative rotative efficiency for each AIS period

6.13 Fuel Consumption

The daily fuel consumption is directly proportional to the delivered power of the ship. It is calculated as shown in Equation 6.14.

$$M_{FC} = \frac{P_{D,corrected} \cdot SFOC_{ME} \cdot 24}{\eta_{trans} \cdot 1000 \cdot 1000} \tag{6.14}$$

where:

M_{FC} is the normalized mass of the fuel burned in tons/day
$P_{D,corrected}$ is the normalized delivered power in Watts, calculated in Equation 6.13
$SFOC_{ME}$ is the specific fuel oil consumption of the main engine in kg/kWh
η_{trans} is the transmission efficiency

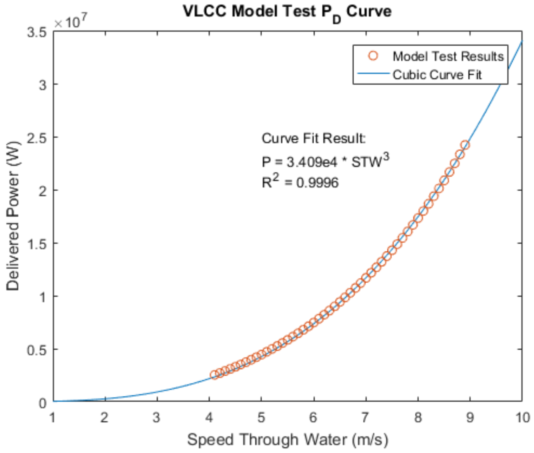
6.14 Fuel Index

To compare the performance of the vessel over time, a fuel index for each noon report period is calculated. As the engine power of a ship at lower Froude numbers (when resistance is mainly due to friction) is roughly proportional to the speed of the vessel cubed ($P \propto V^3$) [11], it stands to reason that the fuel use is also proportional to the speed cubed. This relation can be seen in Figure 6.2, which shows that cubic curves fit well to the model test results for both ship types within the operating speed range. Therefore, to linearize the results and to be able to determine a trendline of ship performance, the fuel index is calculated by dividing the fuel consumption by the speed cubed, as shown in Equation 6.15. As the fuel index is a ratio of engine power to ship speed, a lower fuel index value indicates better vessel performance.

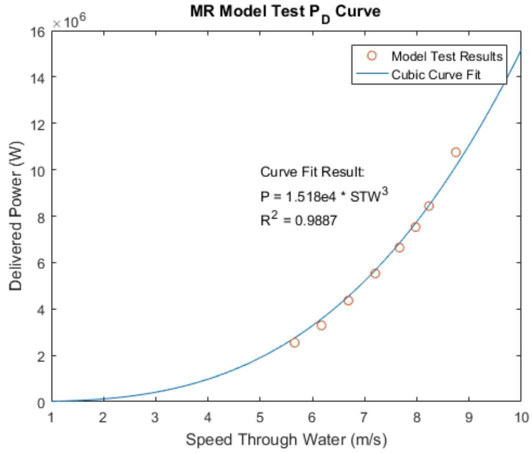
$$\text{Fuel Index} = \frac{M_{FC}}{STW^3} \tag{6.15}$$

where:

M_{FC} is the normalized mass of the fuel burned in tons/day
STW is the speed through water, calculated in Equation 5.1



(a) VLCC Model Test P_D Cubic Fit



(b) MR Model Test P_D Cubic Fit

Figure 6.2: Cubic Curve Fit of Delivered Power

7 Model 1 Results

This section describes the output and results when analyzing the vessels using the first model developed in this thesis.

7.1 Example Output

The first model developed in this thesis analyzes the performance of a ship for each specific voyage. The performance is measured by way of daily fuel consumption, normalized for the effects of waves, wind, water properties, and loading conditions. The program automatically outputs a voyage report with plots showing the measured and normalized fuel consumption of the ship, as well as the route taken by the ship during the voyage. Examples of these plots are shown in Figures 7.1 and 7.2. The plot of the route taken by the ship only shows the data points which were used in the analysis; all other data points have been filtered out. An example voyage report is included in Appendix B. Reports for all voyages by all vessels are available in the electronic voyage report supplement included with this thesis.

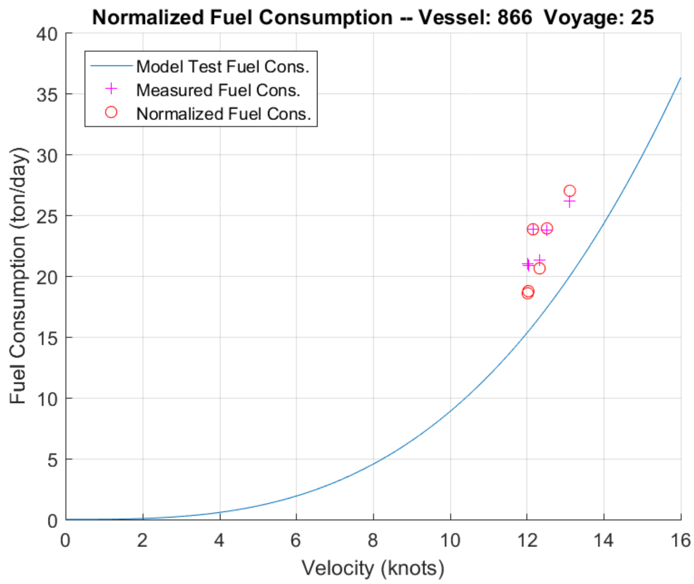


Figure 7.1: Example of Fuel Consumption Plot

The results of each voyage analysis are stored in a database. This allows for a comparison of the performance of a ship on one voyage to another, and also the comparison of one ship to its sister ships. Due to the hindcast data set not having wave data for certain locations, results for periods of transit with missing wave data are marked in the voyage report and database as having 'missing wave info' and are not used in the future long term analyses.

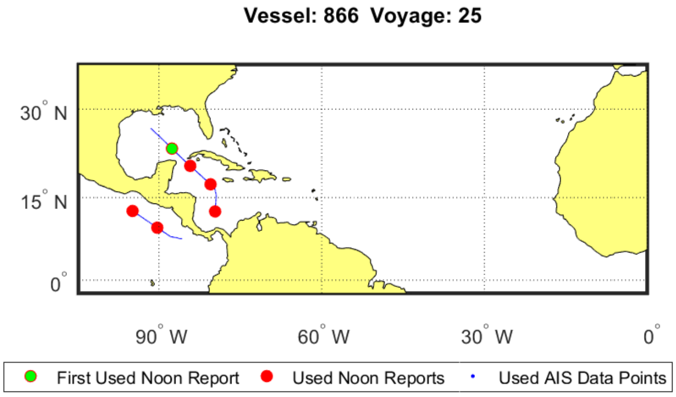


Figure 7.2: Example of Route Plot

7.2 Model 1 Performance Analysis

The results of Model 1 were analyzed in two ways. First, the results for each ship using only the static filters are compared to the results from the noon report method. Using only the static filters, which filters out data outside of the desired draft range and for when required AIS data in not available, shows the effect of the difference in the calculated speed through water as well as the effect of the different methods used for added resistance calculations. Second, the results for each ship using both the static and dynamic filters are compared to the results using only the static filters. This comparison shows the effect of dynamic situations (acceleration and maneuvering) on the overall performance analysis of each ship.

7.2.1 VLCC Analysis

7.2.1.1 Vessel 885

The performance of Vessel 885 is analyzed over nine voyages between January 2016 and November 2016. According to the data set provided, Vessel 885 did not have a hull or propeller cleaning during the analysis period. Therefore, all available data was analyzed together. The performance analysis results using only the static filters is shown in Figure 7.3.

Using the static filters, Model 1 and the noon report method yield similar results. In both cases, the linear trendline fit to the fuel index indicates that the fuel consumption of the vessel increases over time, which is an expected result. As the difference in speed through water measurements between the speed log and the calculation is small (0.2 m/s), it makes sense that both models yield results which are close. In this case, the difference in the fuel index is mainly due to differences in reported weather conditions from the hindcast data, and from differences in the added resistance calculation methods between Model 1 and the noon report methods.

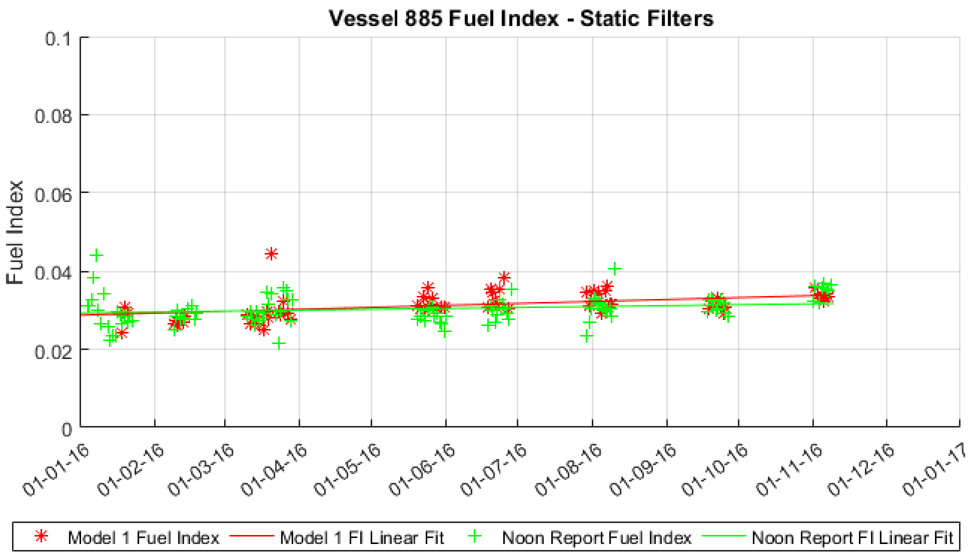


Figure 7.3: Vessel 885 Fuel Index - Static Filters

A comparison of the performance analysis using static versus static and dynamic filters is shown in Figure 7.4.

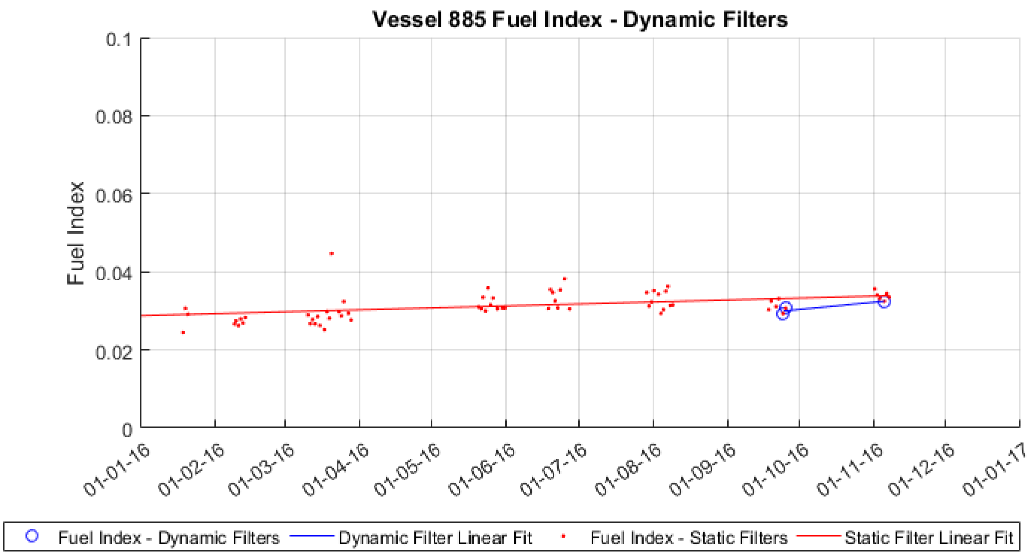


Figure 7.4: Vessel 885 Fuel Index - Dynamic Filters

When using the static filters, there are over 70 noon reports which have been analyzed for Vessel 885. However, after filtering the data to eliminate noon reports which include significant periods of acceleration or maneuvering, only three noon reports remain. With so few points remaining for analysis, it does not make sense to put much emphasis on the slope of the trendline. However, it is clear that the noon reports which remain have lower fuel indexes than the others on the same voyage without the dynamic filters. It makes sense that the fuel indexes for these points are lower, as these cases best represent the steady state condition for the ship, and do not include the added resistance (and thus increased fuel consumption) experienced by the ship during acceleration and maneuvering.

7.2.1.2 Vessel 889

Vessel 889 only has one voyage in March 2016 which was analyzed. Figure 7.5 shows the performance analysis results of Vessel 889 using only the static filters.

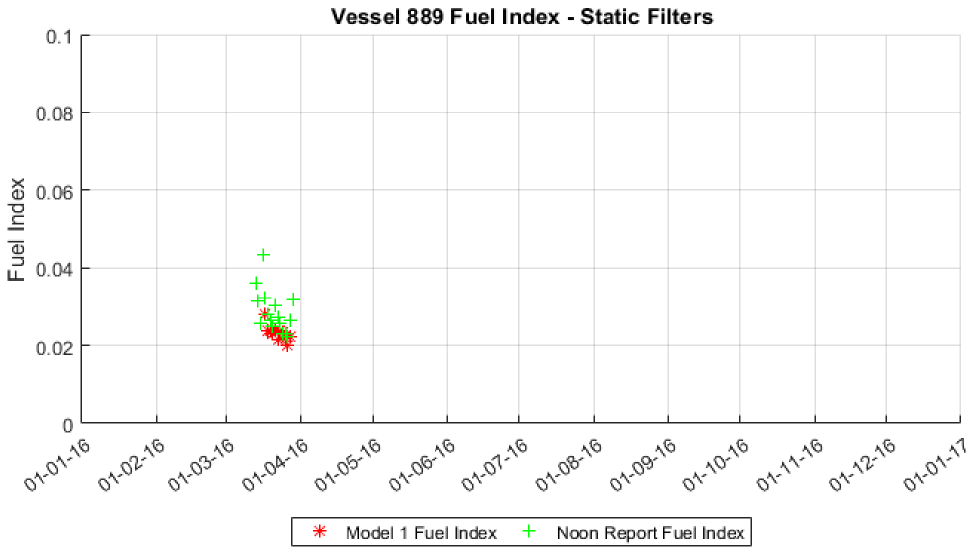


Figure 7.5: Vessel 889 Fuel Index - Static Filters

Unfortunately, there is only one voyage which can be analyzed using Model 1, as the data for all other voyages have been filtered out. Therefore, it is not possible to analyze the performance of Vessel 889. Because all data points shown are from eleven consecutive days from the same voyage in March 2016, it is impossible to fit a meaningful trendline to the fuel index results. Furthermore, once the dynamic filters have been used (acceleration and maneuvering filters), all data was filtered out from the analysis.

7.2.1.3 Vessel 891

The performance of Vessel 891 is analyzed over seven voyages between January 2016 and December 2016. The data set indicates a hull and propeller cleaning in September 2016. Figure 7.6 shows the results of the performance analysis of Vessel 889 using only the static filters.

For Vessel 891, there is a large difference in calculated fuel indexes using Model 1 versus the noon report method. This large difference is almost entirely due to the difference in speed log measurements from the calculated speed through water. The speed log measurements read between 0.5 m/s and 1.0 m/s low from the actual speed

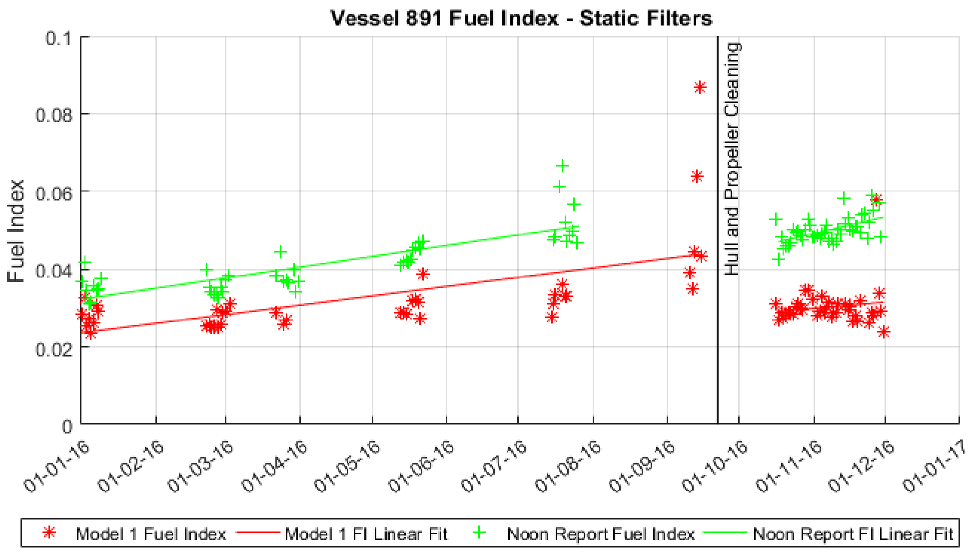


Figure 7.6: Vessel 891 Fuel Index - Static Filters

through water. Because the speed through water used is incorrectly low, the fuel index (which is divided by speed through water to the power of three) ends up being much higher than in reality. If the incorrect speed through water measurements are used, the analysis of the ship performance will show artificially poor performance of the ship.

Still, even with the large difference in calculated fuel indexes, the results of Model 1 and the noon report method do show agreement in terms of the trend of the fuel indexes. Both methods show the fuel index increasing over time, which is expected as the hull condition and performance degrades. Then, after a hull and propeller cleaning takes place and hull condition is restored, the fuel index returns to a lower level. It should be noted that the voyage which took place in September 2016 could not be analyzed using the noon report method because the ship's speed was out of range for that method.

A comparison of the performance analysis using static versus static and dynamic filters is shown in Figure 7.7. After the dynamic filters were applied so that the ship could be studied in the steady state condition, the number of noon reports used was significantly reduced, as expected. Still, there appears to be sufficient data to make an analysis. The trends of the fuel index when analyzing Vessel 891 using just the static filters and when using both the static and dynamic filters are very similar. As the hull condition degrades over time, the results of both filtering methods show an increase in fuel index. Furthermore, after the hull and propeller cleaning, both fuel index calculations drop to lower levels.

Surprisingly, the magnitude of the trendline for the steady state condition is actually higher than that of the condition which includes acceleration and maneuvering periods. This is not an expected result. This appears to be in large part due to the highest fuel index values calculated during the September 2016 voyage which,

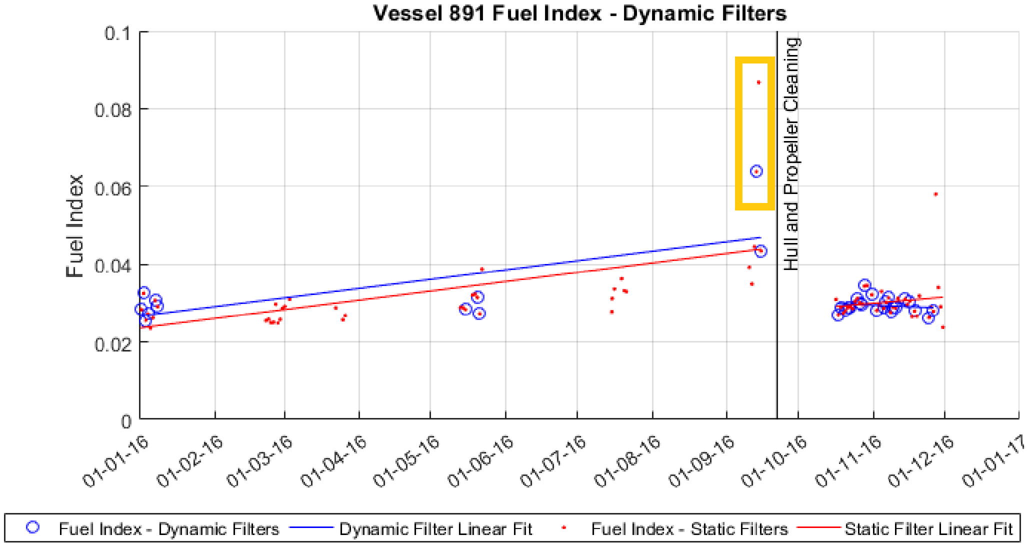


Figure 7.7: Vessel 891 Fuel Index - Dynamic Filters

because they are equally weighted in the trendline calculations, have a large effect on the slope of the trendline. Those two data points, identified in the yellow box, have fuel indexes of over 0.06, which is 40% larger than most data points, and they have a significant effect on the trendline slope. Even though they were not removed by the dynamic filters, the high fuel indexes likely indicate that the ship was traveling in unfavorable conditions during that time, such as a high sea state, restricted waters, or a high traffic area requiring atypical ship operations. To see the effect of these points on the trendline analysis, the noon reports for these points were manually removed and the trendlines were reanalyzed. The modified performance analysis using static versus static and dynamic filters is shown in Figure 7.8.

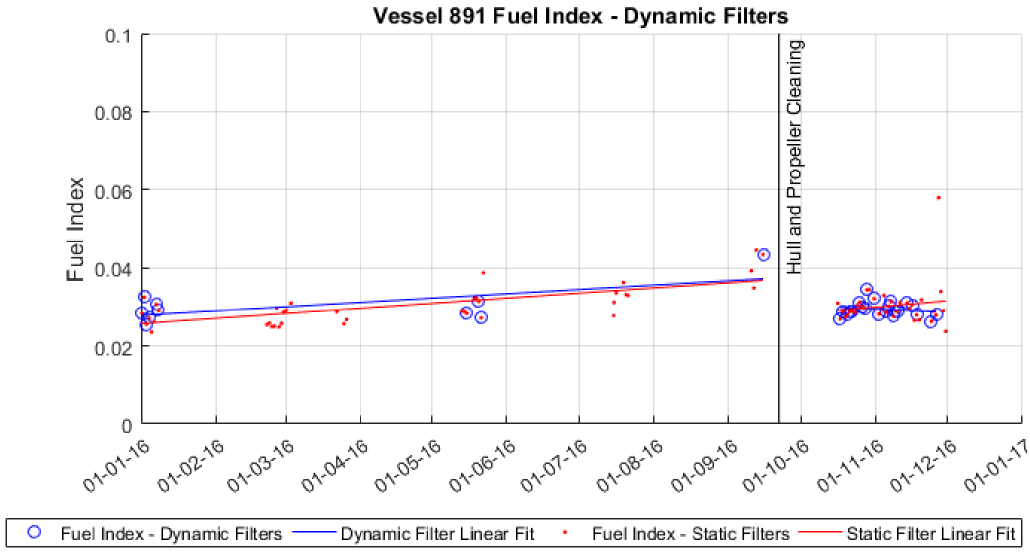


Figure 7.8: Vessel 891 Fuel Index - Dynamic Filters - Modified

Once the two outlier points were removed, the resulting slopes have smaller slopes than before, indicating a slower decrease in performance over time. The trendline for the steady state condition is still higher than when analyzing the conditions which involve acceleration and maneuvering; however, the difference in magnitude is small, and the trendlines converge in September 2016 prior to the hull and propeller cleaning.

7.2.1.4 Comparison of VLCC Performance

Due to the filters that are used, there are large time gaps in the analysis and at times only few data points available for analysis. However, even with the limited number of data points, the results of this analysis look promising. The trendlines for fuel index for both Vessels 885 and 891 show an increase in fuel consumption over time. Furthermore, after a hull and propeller cleaning occurred, there was a drop in the fuel index measurements showing an improvement in performance. These trends are expected when doing vessel performance analyses. The fuel consumption of a ship is expected to increase over time due to hull and propeller fouling, and is also expected to drop after hull and propeller cleanings take place and the fouling is removed.

From the fuel index, it is possible to determine when a ship no longer meets the charterparty criteria for fuel consumption. The assumed charterparty fuel consumption for the VLCCs is 72 tons per day when operating at 13 knots. Thus, the fuel index for this condition would be $(72\ \text{tons/day})/(13\ \text{knots})^3 = 0.033$. Using the trendlines for the fuel index, it can be seen that Vessel 885 failed to meet the charterparty criteria beginning around September 2016, and Vessel 891 failed to meet the charterparty criteria beginning around June 2016. However, after Vessel 891 had a hull and propeller cleaning, the ship was once again able to meet the charterparty criteria.

A plot comparing the performance of the VLCCs using both the static and dynamic filters is shown in Figure 7.9. Based on the fuel indexes, the performance of Vessel 885 and Vessel 891 appear to be comparable. Although Vessel 885 is only analyzed over a short period, the trendline magnitude and slope are similar to periods of Vessel 891's performance. The analysis does not indicate any significant difference of performance between the two ships. This is a different result than determined in the previous thesis [3]; however, the previous thesis was only based on a very limited number of voyages, and thus may not have been indicative of the true performance of the VLCCs.

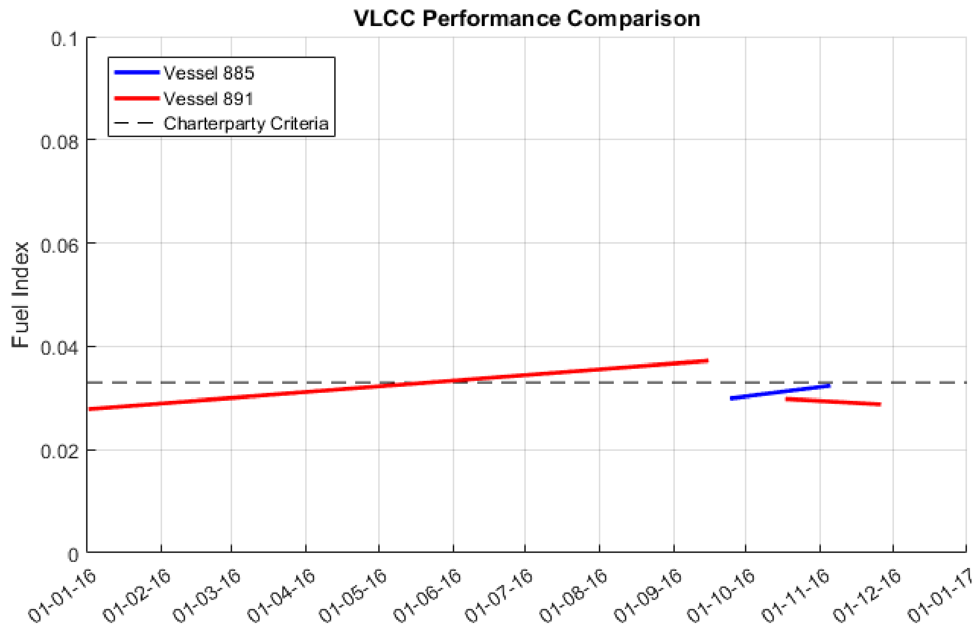


Figure 7.9: Comparison of VLCC Performance

7.2.2 MR Analysis

7.2.2.1 Vessel 856

The performance of Vessel 856 is analyzed over eight voyages from December 2015 through December 2016. The data set indicated that a propeller cleaning occurred in September 2016. Figure 7.10 shows the performance analysis results of Vessel 856 using only the static filters.

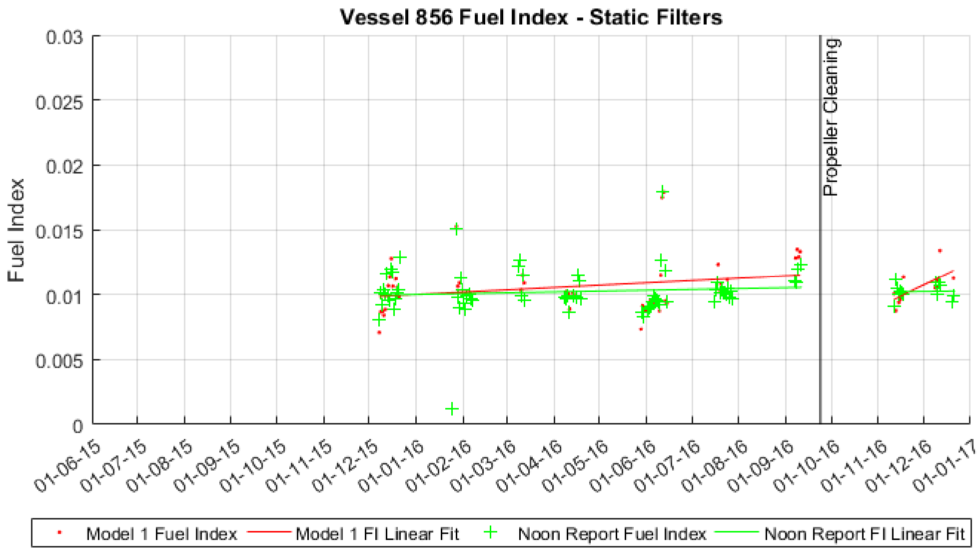


Figure 7.10: Vessel 856 Fuel Index - Static Filters

Using only the static filters, the results using Model 1 and the noon report method yield similar results. The linear trendlines show an increase in fuel index over time, which indicates a drop in vessel performance. Then, after a propeller cleaning occurred, the fuel index returned to a lower level. As the difference in speed through water measurements between the speed log and the calculation is small (0.2 m/s), it makes sense that both models have similar results. In this case, the difference in the fuel index is mainly due to differences in reported weather conditions and the added resistance calculation methods between Model 1 and the noon report method.

A comparison of the performance analysis using static versus static and dynamic filters is shown in Figure 7.11. After the dynamic filters are used, the performance of Vessel 856 can only be analyzed between April 2016 and December 2016. During this time, the results using both the static and dynamic filters continue to show that the fuel index increases over time prior to the propeller cleaning. It can also be seen that the fuel index values when using the dynamic filters have some of the lowest calculated fuel indexes (with one exception during June 2016). Again, it is understandable that when the dynamic filters are applied, the remaining fuel indexes will be lower, as these cases best represent the steady state condition for the ship, and do not include the added resistance experienced by the ship during acceleration and maneuvering.

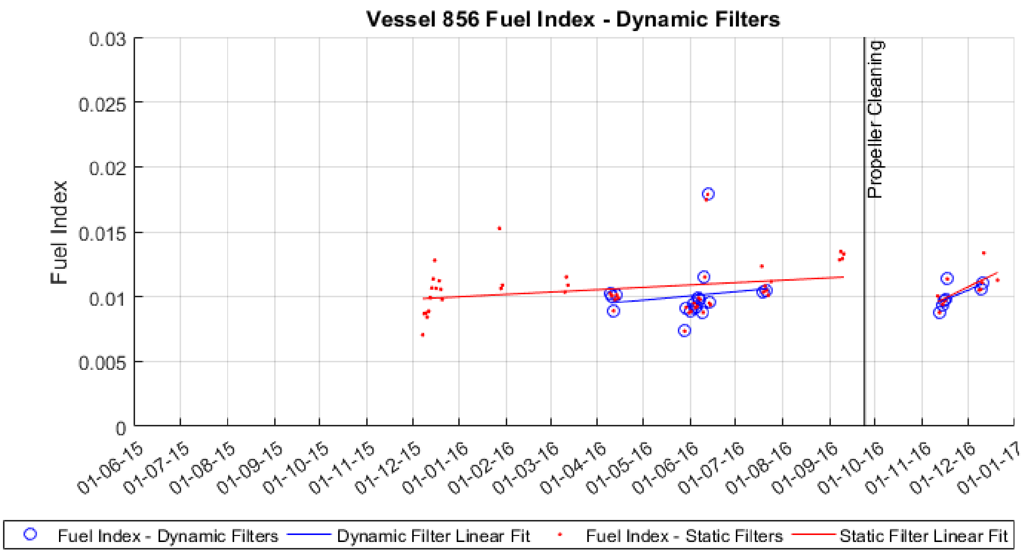


Figure 7.11: Vessel 856 Fuel Index - Dynamic Filters

After the propeller cleaning occurs, the performance analysis using only the static filters and using both the static and dynamic filters yield nearly identical results. Both show that the calculated fuel indexes reduced to a lower level after the propeller cleaning occurred. Not much emphasis should be put on the steeper slopes of the trendlines after the propeller cleaning. As the number of data points used is limited, the slopes are not trustworthy until additional voyages can be analyzed.

7.2.2.2 Vessel 858

The performance of Vessel 858 is analyzed over ten voyages from July 2015 through December 2015, and one voyage in December 2016. According to the data set, two hull cleanings were performed on Vessel 858 during the analysis time period: one in July 2016 and one in August 2016. Figure 7.12 shows the performance analysis results of Vessel 858 using only the static filters.

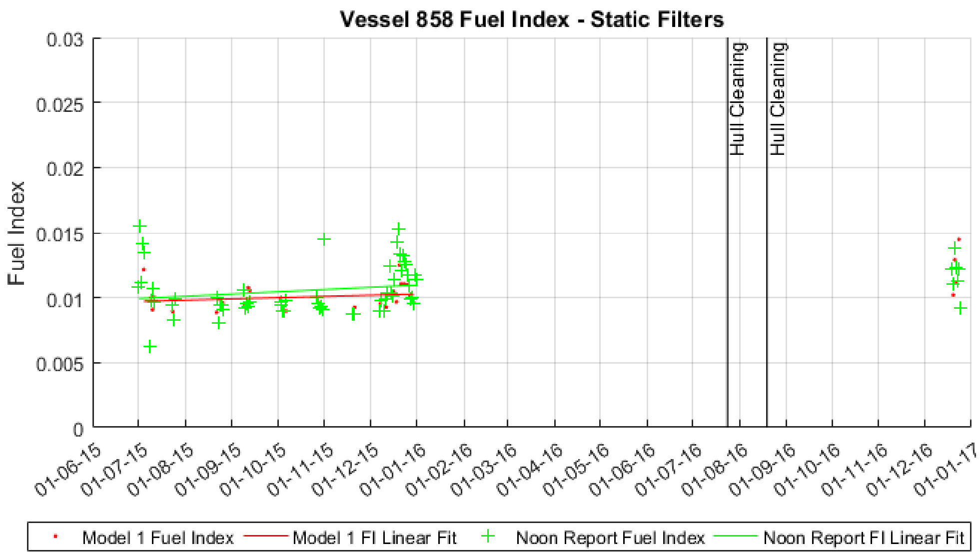


Figure 7.12: Vessel 858 Fuel Index - Static Filters

Prior to the hull cleanings, the fuel index values calculated using Model 1 agree well with the values calculated using the noon report method. There appears to be a much larger scatter during some of the voyages analyzed using the noon report method, especially during the first and last voyages analyzed. However, the overall trendlines show similar outcomes. Both trendlines also show slight positive slopes, indicating a decrease in hull performance over time.

As there is only one voyage which was analyzed after the hull cleanings were completed, it is not possible to analyze the impact of the hull cleanings.

A comparison of the performance analysis using static versus static and dynamic filters is shown in Figure 7.13. The results do not change significantly when using both the static and dynamic filters. The fuel index trendlines are very close in magnitude, with only slight differences in slope. When using the dynamic filters, the trendline typically has a slightly higher magnitude but with a shallower slope. The trendlines using the static filters and using both the static and dynamic filters converge in December 2015.

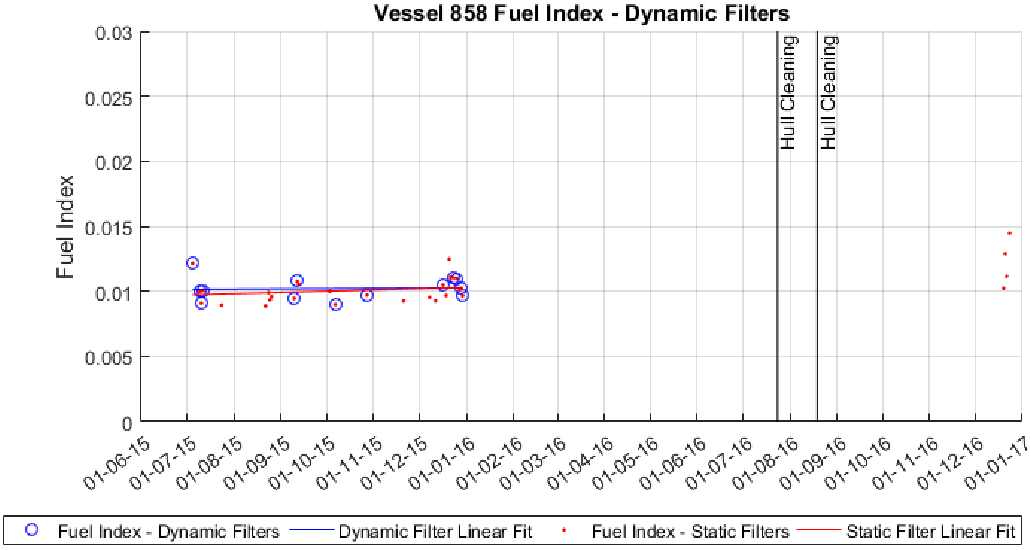


Figure 7.13: Vessel 858 Fuel Index - Dynamic Filters

7.2.2.3 Vessel 864

The performance of Vessel 864 is analyzed over nine voyages from November 2015 through December 2016. According to the data set, two propeller cleanings were performed on Vessel 864 during the analysis time period: one in July 2016 and one in September 2016. Figure 7.14 shows the performance analysis results of Vessel 864using only the static filters.

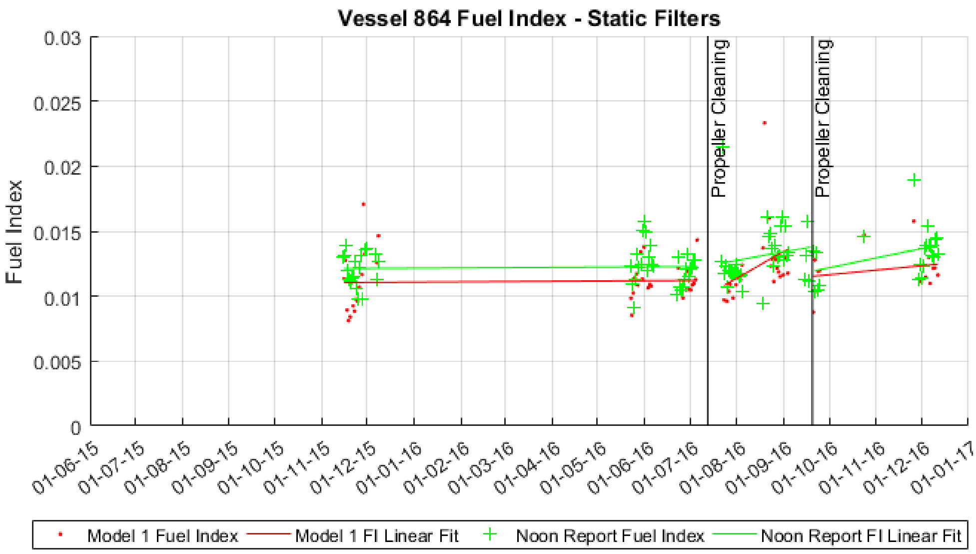


Figure 7.14: Vessel 864 Fuel Index - Static Filters

Vessel 864 has three separate periods during which the performance of the ship can be analyzed. The first period is between November 2015 and early July 2016.

There is a large gap of data in the middle of this period due to the filtering of data. However, the trendline fit to the remaining data indicates that the fuel index remained approximately constant during this time period. This is not an expected result over such a long time period (eight months), but without data for intermediate voyages, it is impossible to make any further judgments.

Propeller cleanings are noted in the middle of July 2016 and September 2016. Two voyages are analyzed between these propeller cleanings. The fuel indexes calculated after the first propeller cleaning are roughly the same as prior to the propeller cleaning. However, the slope of the trendline after the first propeller cleaning becomes steep. This steep decrease in performance, combined with the knowledge that another propeller cleaning occurred only two months later, indicate that the propeller cleaning may have been of poor quality.

After the final propeller cleaning, two additional voyages are analyzed. The fuel indexes calculated after this propeller cleaning return to the levels seen prior to the first propeller cleaning. The trendline in this period also has a shallower, more typical slope.

Interestingly, for Vessel 864, whose speed log appears to be reading correctly, the trendlines calculated from the fuel indexes from Model 1 and the noon report method have the same slope but show a consistent difference in magnitude throughout the analysis. After some investigating, it appears to be mostly due to a systematic difference in recorded wave height and direction versus those taken from the hindcast data. The difference of measurements for wave height and direction for an example voyage of Vessel 864 is shown in Figure 7.15. As described in Section 6.7, the wave correction for resistance is only included when the direction is ± 45 degrees ($\pm\pi/4$ radians) off the bow. The measurements in Figure 7.15 show that the recorded wave directions from the noon reports are rarely within this range. Conversely, the hindcast data shows many days when the waves are within the range for correction. Furthermore, the magnitude of significant wave height from the noon reports is consistently lower by one meter, reducing the correction for wave resistance when it occurs. All of these factors combine to make the resistance corrections when using the noon report method lower than those when using AIS data. This in turn leads to a higher calculated fuel consumption, and thus a higher fuel index using the noon report method.

A comparison of the performance analysis using static versus static and dynamic filters is shown in Figure 7.16. After the dynamic filters are applied, the performance of Vessel 864 can only be analyzed between May 2016 and December 2016. The slopes of the trendlines seen when using only the static filters are also seen when using the static and dynamic filters together. Prior to the first propeller cleaning, the fuel indexes calculated appear to remain constant. After the first propeller cleaning, the fuel index trendline has a steep slope. After the second propeller cleaning, the fuel index trendline returns to a shallower trendline. It can also be seen that the fuel index values for the periods analyzed after using the dynamic filters are typically the lowest calculated fuel indexes, resulting in trendlines which are lower in magnitude

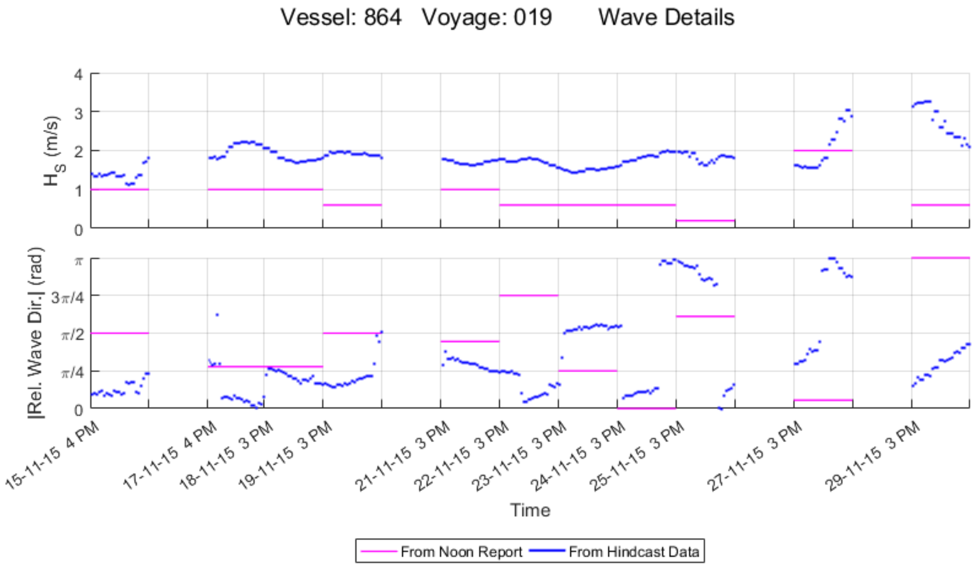


Figure 7.15: Different in Wave Details Between Noon Reports and Hindcast Data

than when using only the static filters. Again, it is understandable that when the dynamic filters are applied, the remaining fuel indexes will be lower, as these cases best represent the steady state condition for the ship and do not include the added resistance experienced by the ship during acceleration and maneuvering.

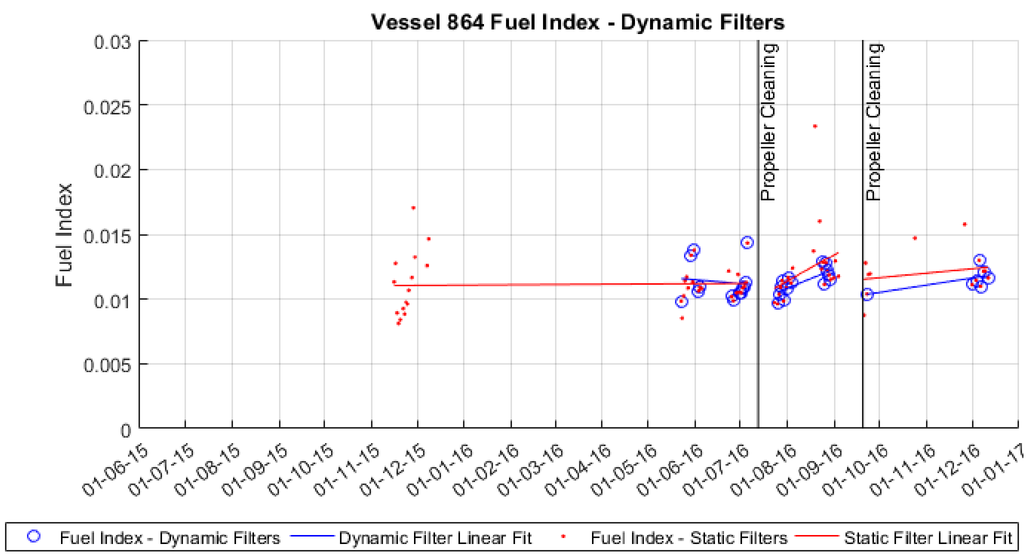


Figure 7.16: Vessel 864 Fuel Index - Dynamic Filters

7.2.2.4 Vessel 866

The performance of Vessel 866 is analyzed over eleven voyages from November 2015 through November 2016. According to the data set, several cleanings were performed on Vessel 866 during the analysis time period: a hull and propeller cleaning in September 2015, a hull cleaning in November 2015, a propeller cleaning in May 2016, and a hull and propeller cleaning in September 2016. Figure 7.17 shows the performance analysis results of Vessel 866 using only the static filters.

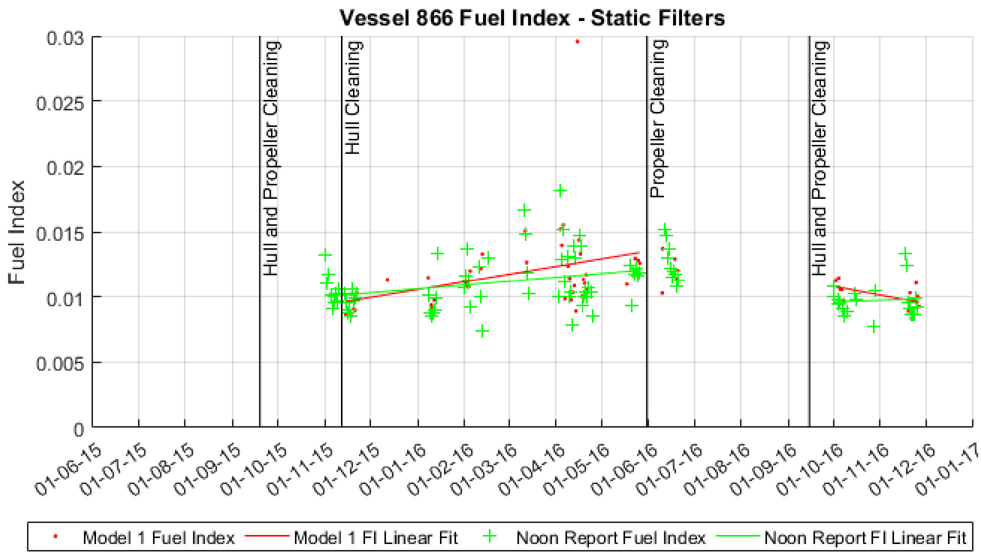


Figure 7.17: Vessel 866 Fuel Index - Static Filters

Due to the distribution of voyages, it is only possible to fit trendlines to the data for two periods: between the hull cleaning in November 2015 and propeller cleaning in May 2016, and after the hull and propeller cleaning in September 2016. In the first period, the results using Model 1 and the results using the noon report method show similar results. The trendlines using both methods both have a positive slope, indicating a decrease in vessel performance during this time. The noon report method tends to result in more scatter in fuel index values. In the second period analyzed, the magnitudes of the fuel indexes have dropped to lower levels as expected after a hull and propeller cleaning. Both methods yields similar magnitudes, although the trendline from the model developed in this thesis has a negative slope, meaning that the performance of the ship would get better over time. Unless this increase in performance is due to outside influences, such as onboard engine maintenance which is not covered by this thesis, it is expected that once more voyages can be analyzed, the slope of the trendline will change directions and return to an expected positive direction.

A comparison of the performance analysis using static versus static and dynamic filters is shown in Figure 7.18. Once the dynamic filters are applied, the performance of Vessel 866 can only be analyzed for two short periods: between November 2015 and January 2015, and between October 2016 and November 2016. The slopes of the trendlines seen when using only the static filters continue to be seen when using the static and dynamic filters together. In the first period, it can also be seen that the fuel index values for the periods analyzed after using the dynamic filters typically are lowest calculated fuel indexes, resulting in trendlines which are lower in magnitude than when using only the static filters for the same reasons as the previous vessels analyzed. In the second period, as the dynamic filters do not remove many of the voyage points, the fuel index magnitudes end up being very similar when using both filtering methods.

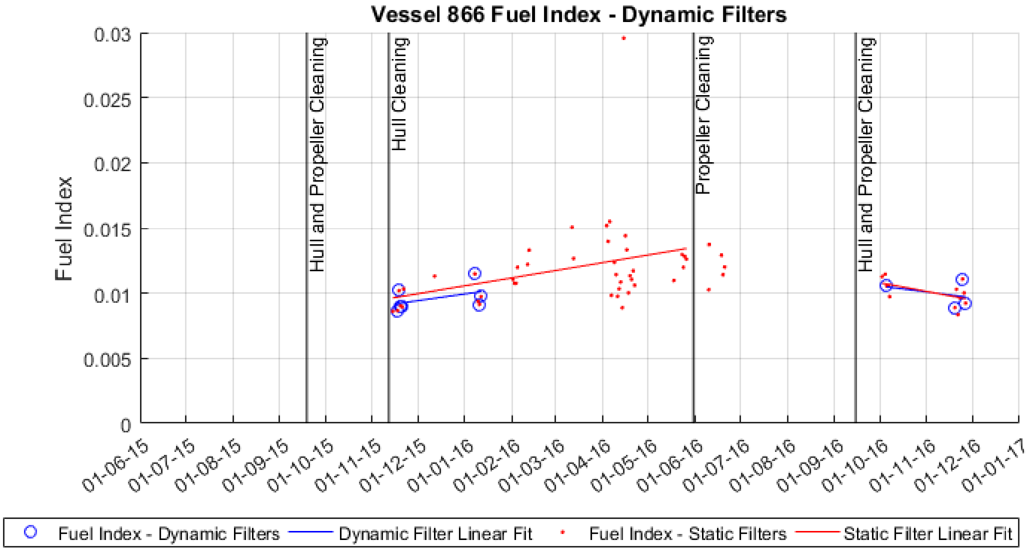


Figure 7.18: Vessel 866 Fuel Index - Dynamic Filters

7.2.2.5 Comparison of MR Performance

The results of the fuel index calculations for the MR tankers follows the expected trends when doing vessel performance analyses. When there is enough data available to fit a trendline, the results show that fuel consumption of the MRs tends to increase over time, and then again decreases after a hull or propeller cleaning.

The assumed charterparty fuel consumption for the MRs is 22.5 tons per day when operating at 13 knots. Thus, the fuel index for this condition would be $(22.5\ \text{tons/day})/(13\ \text{knots})^3 = 0.010$. Using the trendlines for the fuel index, it can be seen that Vessel 856 failed to meet the charterparty criteria beginning around June 2016, Vessel 858 remained at that criteria for most of its operations, Vessel 864 did not meet the charterparty criteria, and Vessel 866 failed to meet the charterparty critera around January 2016, but was able to once again meet the criteria after a hull and propeller cleaning.

A plot comparing the performance of the MRs using both the static and dynamic filters is shown in Figure 7.19. The performance of Vessel 856, Vessel 858, and Vessel

866 all appear to be similar, with fuel indexes ranging between 0.009 and 0.011 throughout the analysis. However, the fuel indexes for Vessel 864 are clearly higher than the other vessels, with the minimum fuel index above 0.01. It appears that Vessel 864 is not operating in the same manner as the other MRs. This is a different result than from the previous thesis, which concluded that all of the MR tankers appear to perform similar [3].

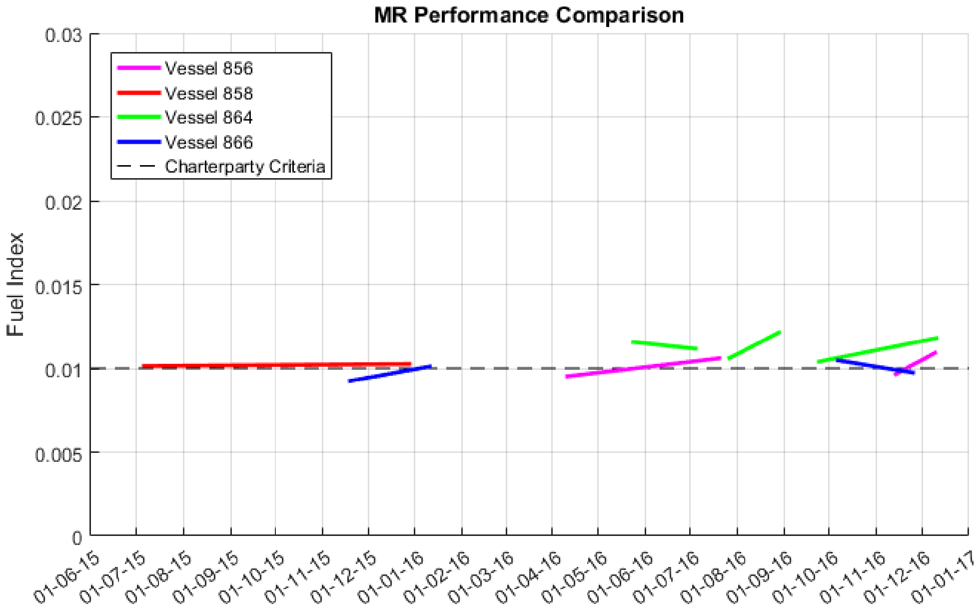


Figure 7.19: Comparison of MR Performance

7.3 Model 1 Outcome

There are two major outcomes from the comparisons of Model 1, which uses AIS data, versus the noon report method, which only uses noon report data. The first outcome relates to the number of data points in each analysis. The number of data points resulting from using the dynamically filtered data is significantly lower than the number of data points from the noon reports. Having detailed operational data allows for removal of the data points which are measured during undesirable conditions causing inaccurate performance analysis results. However, in Model 1 which still relies on daily noon reports, this results in many full noon reports being removed. If the undesirable situation occurs during one hour and cannot be used, the whole noon report has to be skipped from the analysis. Thus, even though the quality of the data may be better, it also means that there may not be enough data in the end to properly analyze the ship performance. This is the case of Vessel 885 - when using AIS data, there are only three data points over the entire analysis period. It may not be a good idea to put trust in this minimal amount of data.

The second major outcome of the comparison between the two methods is that the calculated fuel index for several of the ships has reduced. In many cases, this can also be attributed to the removal of data points from undesirable conditions. Using the AIS data, the data points which involve acceleration, maneuvering, and atypical locations (such as shallow water removed manually) have been skipped in the analysis. The resistance during these conditions, and thus the fuel use, will always be higher than in the steady state conditions from the model tests. In some other cases, the reduction in fuel index is related to the value used for speed through water. For example, in this analysis, the speed log for Vessel 891 reads low by 0.5 to 1.0 m/s which increases the calculated fuel index. By removing the points of artificially-high fuel use from the analysis, both from undesirable environmental conditions and from incorrect speed readings, the trendline of the fuel index will be lower and closer to the expected value.

8 Model 2 Description - Per Auto-Logged Period

This section describes the second performance analysis model developed in this thesis. This model, which analyzes the vessel performance on a per-auto-logged-entry basis, can be used for vessels with auto-logged propulsion data.

8.1 Model Description

One of the major takeaways from Model 1 was that, by doing the analysis on a per-noon-report basis, the number of remaining data points in each analysis was significantly reduced. In that model, if an undesirable situation occurred at any point during the noon report period, the whole noon report has to be skipped from the analysis. For example, in the end, Vessel 885 only had three data points which could be used to analyze the performance of the ship over an entire year.

The second model in this thesis, hereafter referred to as Model 2, was developed to take advantage of additional auto-logged data. This allows for analysis of shorter time periods and reduces the reliance on the noon reports even further, so that many more data points can be analyzed individually. Model 2 uses a combination of AIS and auto-logged propulsion data and only relies on the noon report data for the ship's draft and air temperature (which in the future could be retrieved from auto-logged or hindcast data, respectively). However, Model 2 can only be used for vessels with auto-logged data for shaft torque and RPM. Currently, only Vessel 891 has enough data to be able to be analyzed with Model 2; however, the model is adaptable to the other vessels should they have additional data acquisition systems installed in the future.

Model 2 relies on the measured shaft torque and propeller RPM to calculate engine power, and then relies mainly on the AIS data to apply corrections to the resistance. A flowchart showing where the data used in Model 2 are retrieved from and how they are used is shown in Figure 8.1.

The implementation of Model 2 in MATLAB follows the process below:

1. Filter data points to eliminate times when the ship is not in the desired condition.
2. Determine the speed through water of the ship by adding the ocean currents in the direction of travel at the specified location and time to the AIS speed over ground values.
3. Determine the density, salinity, and viscosity of the water at the specified location and time from the hindcast data.
4. Determine the significant wave height, wave direction, and wave period of the seas at the specified location and time from the hindcast data.

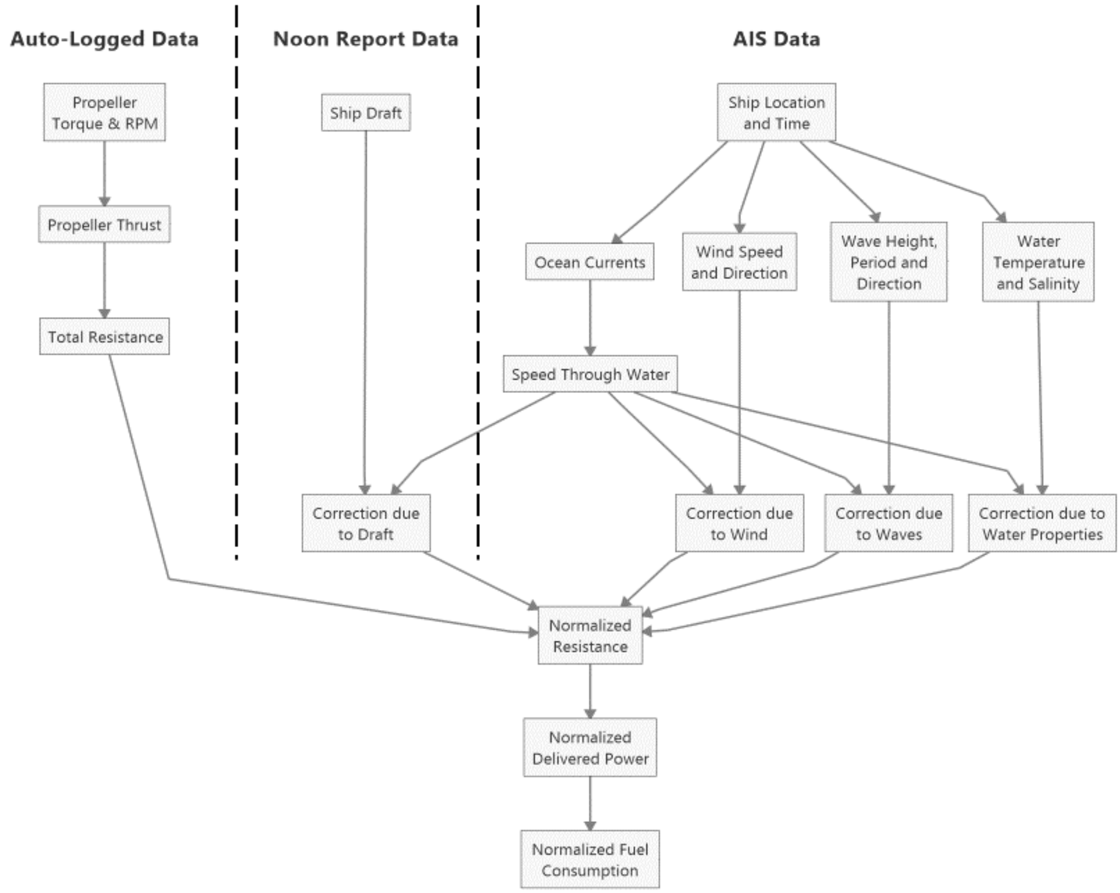


Figure 8.1: Model 2 Flowchart

5. Determine the wind speed and direction at the specified location and time from the hindcast data.
6. Calculate the measured resistance of the ship using the propeller open water curves by determining the operating point based on the measured shaft torque and RPM.
7. Determine the corrections to ship resistance due to the water properties, waves, wind, and draft, and correct the actual resistance based on these calculations.
8. Calculate the normalized delivered power and the fuel index to determine the performance level of the ship over time.

As the shaft torque and RPM are available for each auto-logged period, the fuel use for each period can be calculated individually. Thus, the performance of the ship can also be calculated individually for each auto-logged period. The key steps of the process are described in more detail in the following subsections.

8.2 Assumptions

Similar to Model 1 described in Section 6.2, Model 2 was also developed under the assumption that the decrease in performance is solely due to hull and propeller fouling. The models do not take into account any degradation of engine or transmission performance due to wear or poor maintenance. Furthermore, the thrust deduction factors and relative rotative efficiencies of the ship can be assumed to remain constant over time, independent of hull condition. However, in Model 2, there is now access to propeller RPM for each period. Therefore, the assumption that the wake fraction remains constant is no longer necessary.

In reality, the performance of the ship is affected by the condition of the hull and the condition of the propeller at a certain time. Assuming constant thrust deduction factors (t) and relative rotative efficiencies (η_{RR}), the degradation of ship performance due to the condition of the hull can be represented by a increase in the wake fraction (w). The degradation of ship performance due to the condition of the propeller can be represented by a decrease in the open water efficiency (η_0). Both of the factors come into play when trying to determine the ratio of effective power (P_E) to delivered power (P_D). This ratio is shown in Equation 8.1 below.

$$\frac{P_E}{P_D} = \eta_H \eta_0 \eta_{RR} = \frac{1-t}{1-w} \eta_0 \eta_{RR} \tag{8.1}$$

In the above equation, it can be seen as the hull degrades and the wake fraction increases, the hull efficiency (η_H) also increases. Conversely, as the propeller performance degrades, the open water efficiency decreases. Therefore, these efficiencies "fight" each other when calculating the ratio of effective power to delivered power. Without physically knowing the exact condition of the hull or propeller, it is impossible to calculate the change in magnitude for each of the efficiencies individually.

However, as the effective power of a ship is unaffected by hull performance and the delivered power in a specified hull and operating condition is known, it is possible to determine the ratio of effective power to delivered power at any time. Furthermore, the relative rotative efficiency is known from the model tests. Therefore, the quantity $\eta_H \eta_0$ can be determined. The exact values of the wake fraction and open water efficiency should not matter, so long as the total quantity $\eta_H \eta_0$ for the specified certain condition is held constant. Using this knowledge, it is possible to hold one of the efficiencies constant and change the other, so long as the total quantity remains the same. In this thesis, it was decided to hold the propeller open water efficiency constant and then calculate an adjusted hull efficiency, and thus an adjusted wake fraction. This method yields an inherent assumption that the propeller is in the same condition as during the open water tests. This allows for the use of the measured propeller open water curves in the analysis, while just assuming that the operating point has shifted along the propeller curves. Because the speed and propeller revolution rate are known for each analysis period, the adjusted wake fraction can then be calculated on the basis of the nondimensional torque coefficient curve. It is important to remember that this adjusted wake fraction is not truly representative of the actual condition of the hull, but instead represents the total degradation in condition of the hull and propeller.

It was decided to use the torque measurements rather than the thrust measurements as the onboard measurements for propeller torque are generally more trustworthy than propeller thrust. This is because the propeller thrust is calculated based on shaft axial strain measurements, which are typically an order of magnitude less than the torsional strain measurements used for the propeller torque calculation [7].

8.3 Filtering

The input data for each voyage is filtered using both static and dynamic filters. The static filters ensure that the program only analyzes the situations when the ship is in the desired loading and when there is valid data for each auto-logged period. The dynamic filters ensure that the ship is in a steady state condition. Filtering occurs based on four characteristics:

Static Filters:

1. Any auto-logged periods which are missing the required data fields described in Tables 3.2 and 3.3 are removed, as the analysis cannot be completed without complete information.
2. Any periods during which the ship is operating at a draft significantly different from the design loading condition, taken as ± 2 meters in this analysis, are removed.

Dynamic Filters:

3. Any periods during which the ship is accelerating are removed, taken as when the standard deviation of the speed over ground measurements is greater than 0.10 (discussed previously in Section 6.3).
4. Any periods during which the ship is maneuvering are removed, taken as when the standard deviation of the heading measurements is greater than 0.10.

8.4 Speed Through Water

The speed through water (STW) for each period is calculated as described in Section 5.1.

8.5 Water Properties

The seawater properties for each period are calculated as described in Section 6.5.

8.6 Measured Ship Resistance

The measured resistance is calculated on the basis of the mean measured shaft torque and propeller revolutions of the ship during the AIS period. From the measured shaft torque and revolutions, the nondimensional torque coefficient can be calculated as shown in Equation 8.2.

$$K_Q = \frac{Q_{measured}}{\rho_w n^2 D^5} \tag{8.2}$$

where:

K_Q is the nondimensional torque coefficient
$Q_{measured}$ is the measured torque in Newton-meters
ρ_w is the water density in the experienced water conditions in kg/m^3
n is the propeller revolution rate in revolutions per second
D is the propeller diameter in meters

Using the calculated nondimensional torque coefficient (K_Q), the advance ratio (J) can be interpolated from the open water curves. Then, using J, the nondimensional torque ratio (K_T) and propeller open water efficiency (η_0) can be determined from the open water curves, and an adjusted wake fraction (w_{adj}) can be calculated. It is important to remember that this adjusted wake fraction is not the true wake fraction of the ship, but instead takes into account the fouling of both the hull and propeller, and described in Section 8.2. The adjusted wake fraction can be calculated as shown in Equation 8.3.

$$w_{adj} = 1 - \frac{JnD}{STW} \tag{8.3}$$

where:

w_{adj} is the adjusted wake fraction
J is the advance ratio determined from the open water curves
n is the propeller revolution rate in revolutions per second
D is the propeller diameter in meters
STW is the speed through water of the ship in m/s

Using the nondimensional torque ratio K_T interpolated from the open water curves, the shaft thrust can be calculated as shown in Equation 8.4.

$$T_{measured} = K_T \rho_w n^2 D^4 \tag{8.4}$$

where:

$T_{measured}$ is the measured thrust in Newtons
K_T is the nondimensional thrust coefficient
ρ_w is the water density in the experienced water conditions in kg/m^3
n is the propeller revolution rate in revolutions per second
D is the propeller diameter in meters

The measured ship resistance can then be calculated using the thrust deduction factor (assumed to be unaffected by hull condition as described in Section 8.2), as shown in Equation 8.5.

$$R_{measured} = T_{measured} \cdot (1 - t) \tag{8.5}$$

where:

$R_{measured}$ is the measured resistance in Newtons
$T_{measured}$ is the measured thrust in Newtons
t is the thrust deduction factor

8.7 Correction Due to Waves

The correction to ship resistance due to waves for each period is calculated as described in Section 6.7.

8.8 Correction Due to Wind

The correction to ship resistance due to wind for each period is calculated as described in Section 6.8.

8.9 Correction Due to Draft

The correction for resistance due to differences in draft for each period is calculated as described in Section 6.9.

8.10 Correction Due to Water Properties

The resistance correction due to water properties is calculated as described in Section 6.10.

8.11 Corrected Resistance

The corrected resistance of the ship over each period can then be calculated by subtracting the added resistance from the measured resistance of the ship, as shown in Equation 8.6.

$$R_{corrected} = R_{measured} - R_{AWL} - R_{wind} - R_{ADIS} - R_{AS} \tag{8.6}$$

where:

$R_{corrected}$ is the mean corrected resistance over the AIS period in Newtons
$R_{measured}$ is the measured resistance of the ship, calculated in Equation 8.5
R_{AWL} is the resistance correction due to waves, calculated in Equation 6.7
R_{wind} is the resistance correction due to wind, calculated in Equation 6.9
R_{ADIS} is the resistance correction due to draft, calculated in Equation 6.10
R_{AS} is the resistance correction due to water properties, calculated in Equation 6.11

8.12 Delivered Power

The power delivered to the propeller can be calculated using the ship resistance and calculated parameters, as shown in Equation 8.7.

$$P_{D,corrected} = \frac{R_{corrected} \cdot STW}{\frac{1-t}{1-w_{adj}}\eta_0\eta_{RR}} \tag{8.7}$$

where:

$P_{D,corrected}$ is the normalized delivered power in the auto-logged period in Watts
$R_{corrected}$ is the corrected resistance in Newtons, calculated in Equation 8.6
STW is the speed through water of the ship in m/s
t is the thrust deduction factor
w_{adj} is the adjusted wake fraction, calculated in Equation 8.3
η_0 is the propeller open water efficiency
η_{RR} is the relative rotative efficiency

8.13 Fuel Consumption

The daily fuel consumption can be calculated as shown in Section 6.13.

8.14 Fuel Index

The fuel index can be calculated as shown in Section 6.14.

9 Model 2 Results

This section describes the output and results when analyzing the vessels using the second model developed in this thesis.

9.1 Model 2 Results

The second model developed in this thesis analyzes the performance of a ship for each AIS and auto-logged period. The performance is measured by way of daily fuel consumption based on engine torque and RPM, normalized for the effects of waves, wind, water properties, and loading conditions. The program outputs a plot showing a map of each voyage, the normalized fuel consumption for each period, and a plot showing the fuel consumption performance of the ship over the entire analyzed period. At this point, there are only results for Vessel 891, as that is the only vessel provided with the auto-logged data used in the analysis. However, it is able to be used on any vessel for which there is valid data. An example of a voyage map is shown in Figure 9.1, and an example of a normalized fuel consumption plot for one voyage is shown in Figure 9.2. Reports for all voyages by Vessel 891 are available in the electronic voyage report supplement included with this thesis.

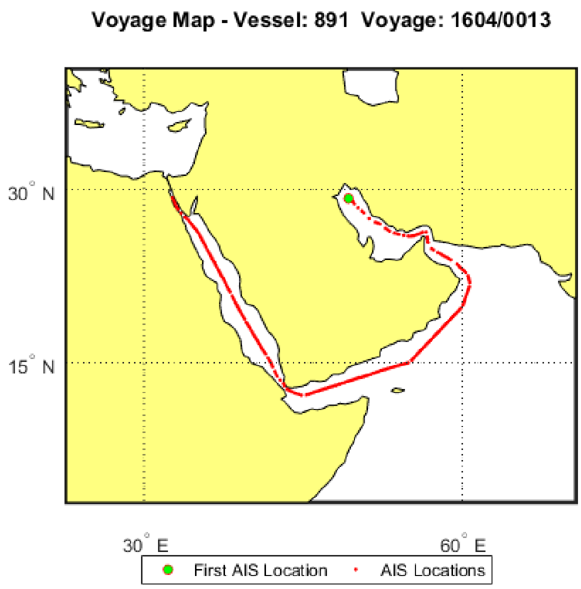


Figure 9.1: Example of Model 2 Voyage Map

The example of the fuel consumption plot clearly shows the importance of applying the resistance corrections for waves, wind, draft, and water properties when analyzing the performance of a ship. Without the correction, it will appear that the ship uses the same fuel consumption rate for many different speeds. This is because the operators of the ship will often set the engine to a constant power level, and the ship will end

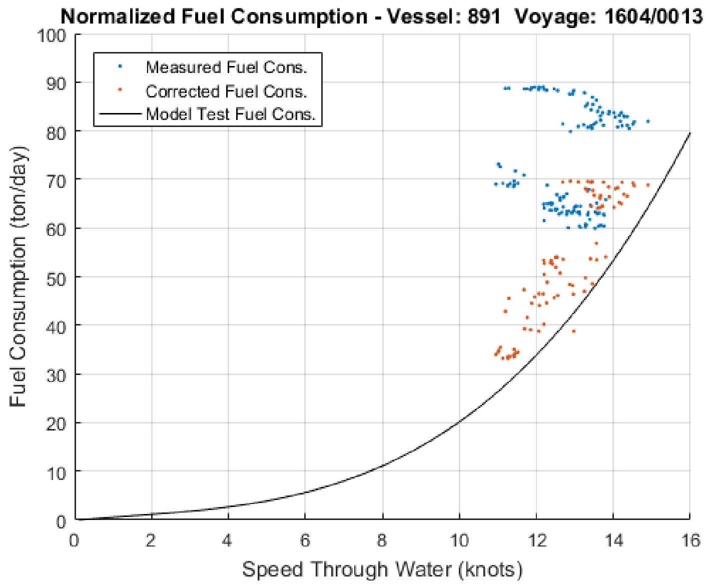


Figure 9.2: Example of Model 2 Fuel Consumption Plot

up traveling at whatever speed the external conditions will allow. However, once the resistance corrections are applied, the fuel consumption curve transforms. While there is still scatter present in the results, the clusters of normalized fuel consumption values begin to reflect a fuel consumption curve of the ship (proportional to speed cubed). The remaining difference between the model test fuel consumption curve and the normalized fuel consumption curve can be attributed the to hull and propeller fouling reducing the performance of the ship.

9.2 Vessel 891

The plot for the fuel index of Vessel 891 using Model 2 is shown in Figure 9.3. The fuel indexes calculated for Vessel 891 using Model 2 show similar trends to expected. Prior to the hull and propeller cleaning, the trendline of fuel index has a positive slope, indicating that fuel consumption increases over time between cleanings. More importantly, even though there are still gaps in the data due to the filters, there are many more points which can be used for the analysis. Using Model 1, prior to the hull and propeller cleaning, there are only ten points which were analyzed. Using Model 2, there are over 1,200 points which were analyzed prior to the hull and propeller cleaning. Using so many additional points in the analysis yields much more trustworthy results.

This upward trend in the trendline prior to the hull and propeller cleaning is influenced significantly by the large scatter in the voyage which took place in September 2016, identified in the yellow box. In this voyage, the largest fuel index is three times as large as the fuel index calculated in any previous voyage. This is a similar result as what was seen using Model 1. During this voyage, the engine power and thus fuel

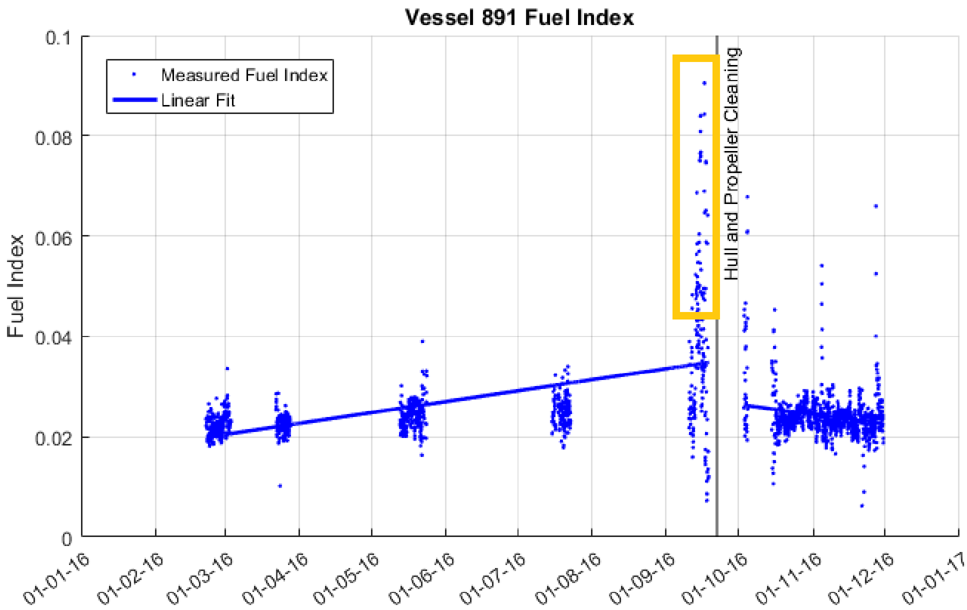


Figure 9.3: Vessel 891 - Calculated Fuel Index

use were significantly larger than expected for the given speed. Even though they were not removed by the filters, the high fuel indexes likely indicates that the ship was traveling in conditions which are not conducive to vessel performance analysis. To see the effect of these points on the trendline analysis, the auto-logged periods during these days (13 September 2016 to 18 September 2016) were manually removed and the trendlines were reanalyzed. The modified performance analysis is shown in Figure 9.4.

When the days with unexpectedly high fuel indexes were manually removed from the analysis, the trendline for Vessel 891 before the hull and propeller cleaning reflects the results from the first model. A positive slope remains, indicating that the performance of the ship degrades over time, albeit slower than before the points were removed.

After the hull and propeller cleaning was completed, the cluster of calculated fuel indexes indicate that the hull performance was improved. However, the trendline for this period actually shows a downward trend in fuel consumption over time, which is not expected. Without knowing any details about the hull condition or antifouling paints used, it is not possible to determine the cause of this downward trend. However, when more data has been collected and can be added to the analysis, it is expected that the trendline will gain a positive slope indicating an increase in fuel consumption over time.

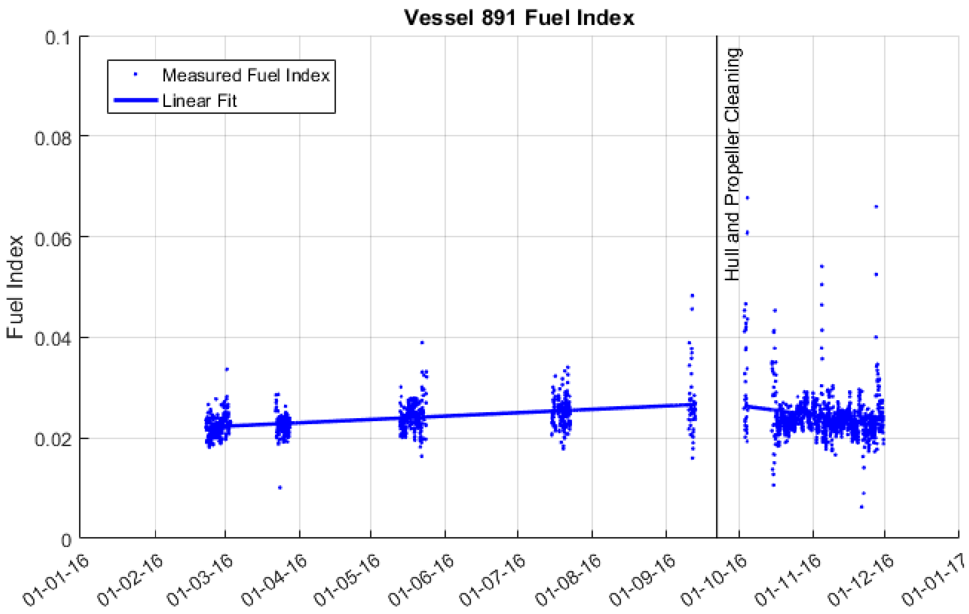


Figure 9.4: Vessel 891 - Calculated Fuel Index - Modified

10 Overall Results

This section discusses the benefit of using AIS and auto-logged data in addition to the noon reports. This section also discusses an example method of using the calculated trendlines to determine when a hull cleaning should be performed.

10.1 Comparison of All Models - Vessel 891

A comparison of the calculated fuel indexes using all three models (Model 1 and Model 2 developed in this thesis and the noon report method from previous thesis) is presented in Figure 10.1. This comparison is only presented for Vessel 891, as it is the only vessel with enough data to allow for use of the second model developed in this thesis.

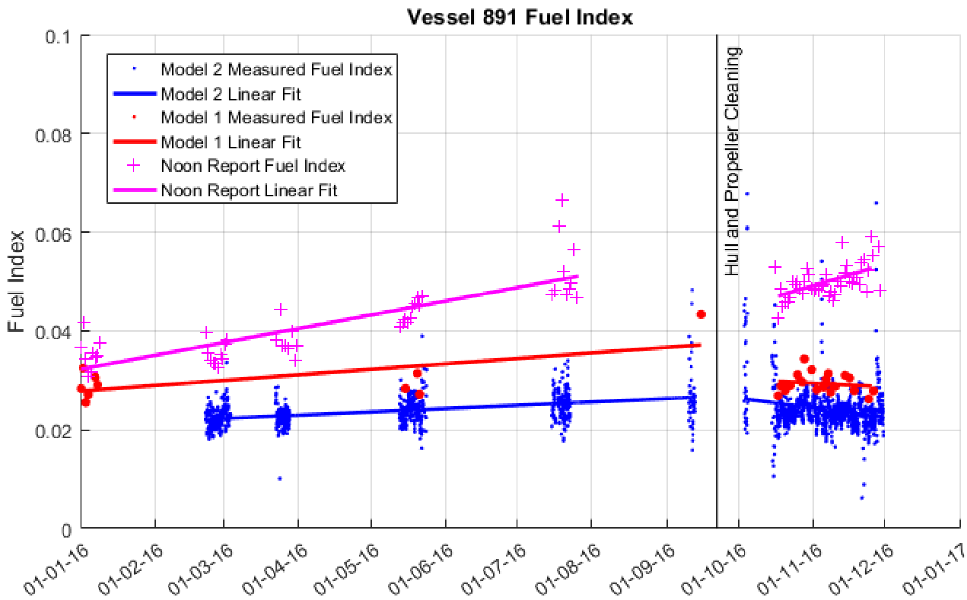


Figure 10.1: Vessel 891 - Fuel Indexes For All Methods

The fuel indexes calculated with Model 2 are consistently less than those calculated with Model 1, and much less than those calculated with the noon report method. Between March 2016 and September 2016, the slope of the trendline calculated in Model 2 is very close to that of Model 1. During this time period, the difference in fuel index between the two models is 0.008. At the charterparty speed of 13 knots, this yields a difference between the two models of over 17 tons per day of fuel. A similar though smaller difference can be seen in the period after the hull and propeller cleaning, although due to the difference in slopes of the trendlines, there difference between the two methods does not remain constant.

The presence of such a large difference between the two methods developed in this thesis is likely a combination of factors. Three potential factors are discussed below:

1. Model 2 was developed using the auto-logged engine power data, as opposed to actual fuel consumption information. By doing this, the inherent assumption was that the engine and transmission efficiencies remain constant throughout the ship's life. However, if the engine or transmission are not performing as designed, or if the engine is operating in a condition such that it's specific fuel oil consumption is higher than the design value, the actual fuel consumption would be larger than calculated. This would lead to an increase in the fuel index calculated in Model 2, bringing the indexes calculated in both models closer together.

2. As Model 2 was developed using the auto-logged data engine power data, it is also subject to errors if the calibration of the sensors are off. The engine power is calculated using a torque meter installed on the shaft. If the engine torque or engine RPM are measured incorrectly, the fuel consumption calculated for that situation would also be incorrect, leading to an incorrect fuel index being calculated.

3. Model 1 was developed using the assumption that all of the main engine fuel consumption listed in the noon report goes towards the propeller. If this is not the case (for example, if the main engine is also driving a shaft generator), then the initial fuel consumption values and thus the delivered power would be artificially high. Thus, the final calculated fuel index would also be artificially high. By lowering the fuel consumption values, the fuel indexes calculated in both models would become closer.

10.2 Hull Cleaning Analysis

Using the fuel index trendlines calculated in this thesis, it is possible to estimate when a hull cleaning should take place based on incurred cost. Because an estimate of the post-cleaning fuel index can be determined based on previous knowledge and the slope of the trendline is known over a certain period, the additional cost incurred per day due to fouling can be calculated. These costs per day can then be summed. Once the additional costs per day surpasses the cost of a hull cleaning, it then makes financial sense for it to occur.

10.2.1 Hull Cleaning Analysis Example

The following example of how the fuel index trendlines can be used is based upon the trendline of Vessel 891 between February 2016 and September 2016 calculated in Model 2. The equation for the fuel index trendline for Vessel 891 is shown in Equation 10.1.

$$FI(x) = 2.177 * 10^{-5} \cdot x - 16.01 \tag{10.1}$$

where:

$FI(x)$ is the fuel index calculated at a certain day

x is the serial date number of day being analyzed. The serial date number represents the whole and fractional number of days from a fixed date (January 0, 0000) in the proleptic ISO calendar.[18]

The additional cost for each day of operation after a hull cleaning can then be calculated as shown in Equation 10.2.

$$\text{Additional Daily Cost } = FuelCost \cdot STW^3 \cdot (FI(x) - FI(start)) \tag{10.2}$$

where:

$FuelCost$ is the price of fuel in dollars per ton

STW is the speed through water of the vessel in the same units as the fuel index

$FI(x)$ is the fuel index calculated at a certain day

$FI(start)$ is the initial fuel index after a hull cleaning

If the fuel price is taken as approximately $300 per ton [6] and an in-water hull cleaning is estimated to be $50,000 [14], it would take 83 days of operation to recap the cost of the hull cleaning as shown in Table 10.1. Note that this hull cleaning cost does not account for any lost revenue or wages for crew during this time period, so the actual payback period would be higher.

Table 10.1: Hull Cleaning Example Calculation

Day	**Date**	**Serial Date**	**Fuel Index**	**Add'l Cost**
0	22-Feb-2016	736382	0.02213	$-
1	23-Feb-2016	736383	0.02215	$36
2	24-Feb-2016	736384	0.02217	$73
3	25-Feb-2016	736385	0.02219	$109
4	26-Feb-2016	736386	0.02222	$146
5	27-Feb-2016	736387	0.02224	$182
↓	↓	↓	↓	↓
79	11-May-2016	736461	0.02385	$1,749
80	12-May-2016	736462	0.02387	$1,785
81	13-May-2016	736463	0.02389	$1,822
82	14-May-2016	736464	0.02391	$1,858
83	15-May-2016	736465	0.02394	$1,895
Cumulative Cost				**$50,024**

11 Conclusion

Two vessel performance analysis models have been successfully developed in this thesis. The first model analyses the ship performance on a per-noon-report basis and can be used for any vessel for which daily fuel consumption values are available. The second model analyses the ship performance on an hourly basis based on statistics calculated from auto-logged propulsion data. Both models normalize the results to remove added resistance due to wind, added resistance due to waves, differences in resistance due to draft, and differences in resistance due to water properties.

Using the AIS and auto-logged data combined with the noon report data, both models filter the initial data to remove any undesirable conditions which would cause an incorrect performance analysis. These situations include when key data are missing, when the ship's draft is significantly different from the design condition, when the ship is accelerating, when the ship is maneuvering, and when there are obvious reporting errors.

Based on the AIS data, both models combine hindcast data for ocean currents with the GPS-based speed over ground to calculate the speed through water of the ships. It has been shown that this method of calculating speed through water stops speed log calibration errors from propagating throughout the calculations, and thus has removed one potential source of error. Some additional scatter has been added into the speed through water measurements due to the coarseness of the hindcast data used; however, it was decided that the benefit of using hindcast data to eliminate the speed log calibrations errors outweighs the error from the minor scatter due to the hindcast data. This error can be reduced in the future by using hindcast data with finer resolution.

Based on the AIS data, both models use hindcast data for wave measurements, wind measurements, and water properties. Studies have shown that it is notoriously difficult to judge wave conditions visually, and that anemometer readings onboard the ships can be inaccurate. Furthermore, onboard measurements for wave conditions and water temperature are only available once per day. It has been shown that it is possible to use AIS position and time information to retrieve unbiased hindcast data for the environmental conditions.

It has been shown that using AIS data in vessel performance analyses can improve the precision of the study. The data gathered from the noon reports is only available on a daily basis. However, the AIS statistics used in this study are available typically on an hourly basis. Furthermore, hindcast data are also available for shorter time periods than once per day. Using AIS data in vessel performance analysis allows for calculations over shorter time periods, therefore capturing more details of the ship operations and allowing for more precise calculations of resistance corrections.

When comparing the models developed in this study versus the noon report method, it has been shown that the calculated fuel index values tend to be lower. This is primarily due to the filtering of undesirable conditions. By removing these undesirable conditions, the situations where the ship appears to be performing worse than designed are removed, and the performance analysis results are closer to the actual performance level of the ship. The results of the fuel index calculations show that the two VLCCs with sufficient data appear to be operating at similar performance levels, and that three of the MRs appear to be operating at similar performance levels while one operates with higher fuel consumption. It has been shown that the techniques used in this thesis correctly show that the performance of the tankers tends to degrade over time, and that hull and propeller cleanings bring the performance back to the desired levels. It is also possible to use the fuel index trendlines to estimate when a hull and propeller cleaning makes sense economically.

11.1 Future Improvements

Even though a lot of work has been put into development of the performance analysis models used in this thesis, there are still improvements which can be added to improve the quality of the results even further. Some of these potential improvements are discussed below.

1. **Use finer AIS data.** Currently, this thesis uses AIS statistical data instead of raw data. However, if raw data or shorter AIS periods were available, it would be possible to improve the analysis. Many noon reports were filtered out of the analysis because data was missing for certain time periods or because the timestamps for the noon reports did not line up with the periods used in the AIS statistics. If raw or finer AIS was used, this problem could be eliminated. Furthermore, the filtering techniques could also be improved by using raw or finer AIS data. Currently, the filtering for maneuvering and acceleration are only based upon the standard deviation of the heading and speed within any AIS period, respectively, although the actual distribution of both of these factors is not know. Filtering could be improved if the model was able to make use the raw data for ship heading and speed, where it would be easier to determine if either maneuvering or acceleration was occurring.

2. **Filter out locations with shallow water or restricted seaways**. When a ship operates in shallow or restricted waters, the ship will experience added resistance due to increased friction or a blockage effect [25]. The models developed in this thesis do not currently filter out data based on location. However, if bathymetric data was available and put into the model, it would be possible to automatically filter the data when the ship is passing through shallow or restricted waters. This would improve the accuracy of the results, as more undesirable conditions would have been removed from the analysis.

3. **Reduce reliance on shipboard measurements.** The models developed in this thesis still rely on the ship's draft and air temperature measurements from the noon reports. It would be possible to reduce the reliance on these measurements by taking the ship's draft from the ship's onboard loading

computer, and by taking the air temperature from hindcast data (which was not done in this thesis only for practicality).

4. **Improve the methods for speed through water calculations.** In this thesis, the speed through water is calculated using speed over ground combined with ocean currents from hindcast data. Although the results show a marked improvement over speed logs with calibration errors, some additional scatter has been added into the results. It may be possible to improve the speed through water by using a "virtual speed log," which combines speed over ground, ocean currents, and speed log measurements to fine tune the results. This method is currently being studied by Eniram [2].

5. **Improve the quality of the hindcast data.** Some of the hindcast data used in this thesis is relatively coarse, both in terms of geographic location and time period. Both the wind data and the ocean current and water property hindcast data used in this thesis are available for 1/4-degree latitude and longitude areas, but are only available for 6-hour and 24-hour periods, respectively. The wave hindcast data are available for 3-hour periods, but only for 1/2-degree latitude and longitude areas. Finer hindcast data are available, but was not used in this thesis due to the difficulty of acquiring and storing large amounts of data. However, if finer hindcast data was used, the results of the analysis are expected to be better.

6. **Adjust wave spectrum used in wave resistance calculations based on location.** The models developed in this thesis assume the Bretschneider wave spectrum for wave calculations globally. The Bretscneider spectrum is valid for fully developed seas is open ocean environments, and it applicable for much of the analysis. However, the Bretschneider spectrum does not represent wave conditions for coastal waters or areas with limited fetch, such as the North Sea and Baltic Sea. Instead, the seas in these locations are better represented by the JONSWAP spectrum [20]. The calculations for added resistance due to waves would be improved if the models included the automatic choosing of the applicable wave spectrum based on location of the ship.

7. **Adjust engine efficiency based on operating condition.** This thesis assumes that the main engine specific fuel oil consumption and transmission efficiency remain constant throughout the analysis. However, this may not always be the case. If the condition of the engine and transmission are known, it would be possible to improve the analysis by adding in these additional factors.

12 Bibliography

[1] Christian Aage. *Wind coefficients for nine ship models, Hya Report No. A-3.* 1st ed. Danish Technical Press, 1971.

[2] Matti Antola, Antti Solonen, and Jussi Pyörre. “Notorious Speed Through Water”. In: *HullPIC’17.* Eniram, 2017, pp. 156–165.

[3] Jimmie Beckerlee. “Ship Performance Monitoring and Analysis”. MA thesis. Danmarks Tekniske Universitet, 2016.

[4] Henk van den Boom, Hans Huisman, and Frits Mennen. “New Guidelines for Speed/Power Trials”. In: *SWZ Maritime* 134 (2013), pp. 18–22.

[5] Lucy Aldous, Tristan Smith, Richard Bucknall. “Low Carbon Shipping Conference”. In: *Noon Report Data Uncertainty.* 2013.

[6] Ship & Bunker. *World Bunker Prices.* Accessed 13 June 2017. URL: `https://shipandbunker.com/prices`.

[7] J. S Carlton. *Marine propellers and propulsion.* 3rd ed. Elsevier, 2012, pp. 376–377.

[8] Copernicus Marine Environment Monitoring Service (CMEMS). *Global Ocean 1/4° Physics Analysis And Forecast Updated Daily.* GLOBAL_ANALYSIS_FORECAST_PHYS_001_015, Data set.

[9] Copernicus Marine Environment Monitoring System (CMEMS). *Global Ocean Wind L4 Near Real Time 6 Hourly Observations.* WIND_GLO_WIND_L4_NRT_OBSERVATIONS_012_004, Data set.

[10] Hisham T El-Dessouky and Hisham Mohamed Ettouney. *Fundamentals of salt water desalination.* 1st ed. Elsevier, 2002.

[11] CAPT Norbert H. Doerry. “Sizing Power Generation and Fuel Capacity of the All-Electric Warship”. In: *IEEE* (2007).

[12] US DOC; NOAA; NWS; National Centers for Environmental Prediction. *Output Fields from the NOAA Wavewatch III® Wave Model Monthly Hindcasts (NCEI Accession 0130693) Version 1.1.* Data set.

[13] Søren Vinther Hansen. “Performance Monitoring of Ships”. PhD thesis. Technical University of Denmark, 2012.

[14] *Hull Coatings for Vessel Performance.* 1st ed. Fathom Focus, 2013.

[15] Miro Kresic and Bruce Haskell. “Effects of Propeller Design-Point Definition on the Performance of a Propeller/Diesel Engine System with Regard to In-Service Roughness and Weather Conditions”. In: *SNAME Transactions* 91 (1983), p. 199.

[16] Lars Larsson, Hoyte C Raven, and J. Randolph Paulling. *Ship resistance and flow.* 1st ed. Society of Naval Architects and Marine Engineers, 2010.

[17] P.C. Liu and T.A. Kessenich. “IFYGL Shipboard Visual Wave Observations VS. Wave Measurements”. In: *Journal of Great Lakes Research* July 1976 (1976), pp. 33–42.

[18] MATLAB. *datenum.* 2017. URL: `https://se.mathworks.com/help/matlab/ref/datenum.html`.

[19] Anthony F Molland. *The Maritime Engineering Reference Book.* 1st ed. Butterworth-Heinemann, 2008, pp. 328–330.

[20] Ulrik Dam Nielsen. *Ship Operations - Engineering Analysis and Guidance.* 2nd. Technical University of Denmark, 2010.

[21] International Maritime Organization. *Automatic Identification System (AIS).* 2017. URL: `http://www.imo.org/en/OurWork/safety/navigation/pages/ais.aspx`.

[22] SP Global Platts. *The IMO's 2020 Global Sulfur Cap.* 2016.

[23] Jani Romanoff. *Kul-24.4140 Ship Dynamics: Lecture 3 - Surface Waves.* 2016.

[24] Prasanta Sahoo. *Lecture Notes E03 305.* Ship Dynamics. 2007, p. 45.

[25] Carlos Guedes Soares. *Marine technology and engineering.* CRC Press, 2011.

[26] International Organization for Standardization. *15016.2 Ships and marine technology - Guidelines for the assessment of speed and power performance by analysis of speed trial data.* 2002.

[27] International Organization for Standardization. *15016.2 Ships and marine technology - Guidelines for the assessment of speed and power performance by analysis of speed trial data.* 2014.

[28] Peter K. Taylor et al. *The Accuracy of Marine Surface Winds from Ships and buoys.* 1995.

A Water Density Calculation

Both the water density and dynamic viscosity can be calculated based on correlation equations depending on temperature and salinity. The seawater density can be calculated as shown in Equation A.1 [10].

$$\rho_w = 10^3(A_1F_1 + A_2F_2 + A_3F_3 + A_4F_4) \tag{A.1}$$

with:

$$\begin{aligned}
B &= ((2)(X)/1000 - 150)/150 \\
G_1 &= 0.5 \\
G_2 &= B \\
G_3 &= 2B^2 - 1 \\
A_1 &= 4.032219G_1 + 0.115313G_2 + 3.26 \cdot 10^{-4}G_3 \\
A_2 &= -0.108199G_1 + 1.573 \cdot 10^{-3}G_2 - 4.23 \cdot 10^{-4}G_3 \\
A_3 &= -0.012247G_1 + 1.74 \cdot 10^{-3}G_2 - 9 \cdot 10^{-6}G_3 \\
A_4 &= 6.92 \cdot 10^{-4}G_1 - 8.7 \cdot 10^{-5}G_2 - 5.3 \cdot 10^{-5}G_3 \\
A &= ((2)(T) - 200)/160 \\
F_1 &= 0.5 \\
F_2 &= A \\
F_3 &= 2A^2 - 1 \\
F_4 &= 4A^3 - 3A
\end{aligned}$$

where:

ρ_w is the seawater density in kg/m^3
X is the seawater salinity in parts per million (PPM)
T is the seawater temperature in Celsius

The dynamic viscosity of the seawater can be calculated for each AIS period as shown in Equation A.2 [10].

$$\mu = (\mu_W)(\mu_R) \cdot 10^{-3} \tag{A.2}$$

with:

$$\begin{aligned}
\ln(\mu_W) &= -3.79418 + 604.129/(139.18 + T) \\
\mu_R &= 1 + As + Bs^2 \\
A &= 1.474 \cdot 10^{-3} + 1.5 \cdot 10^{-5}T - 3.927 \cdot 10^{-8}T^2 \\
B &= 1.0734 \cdot 10^{-5} - 8.5 \cdot 10^{-8}T + 2.23 \cdot 10^{-10}T^2
\end{aligned}$$

where:

μ is dynamic viscosity in kg/m
T is the seawater temperature in Celsius
s is the seawater salinity in gm/kg

The kinematic viscosity of the seawater for each AIS period can then be calculated as shown in Equation A.3.

$$\nu = \mu / \rho_w \tag{A.3}$$

B Example Voyage Report

The following is an example of the voyage report created when using Model 1. Reports for all voyages by all vessels are included in the electronic voyage report supplement.

Vessel: 864; Voyage Name: 25

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
3	23-May-2016 05:00:00	23-May-2016 17:00:00	12.50	0.00 40.43	0.00 42.20	13.20 42.43
9	29-May-2016 14:00:00	30-May-2016 14:00:00	12.50	31.80 40.43	0.00 42.20	0.00 42.43
11	31-May-2016 13:00:00	01-Jun-2016 13:00:00	12.50	29.90 40.43	0.00 42.20	0.00 42.43
14	03-Jun-2016 12:00:00	04-Jun-2016 11:00:00	12.50	27.70 40.43	0.00 42.20	0.00 42.43
15	04-Jun-2016 11:00:00	05-Jun-2016 11:00:00	12.50	29.90 40.43	0.00 42.20	0.00 42.43

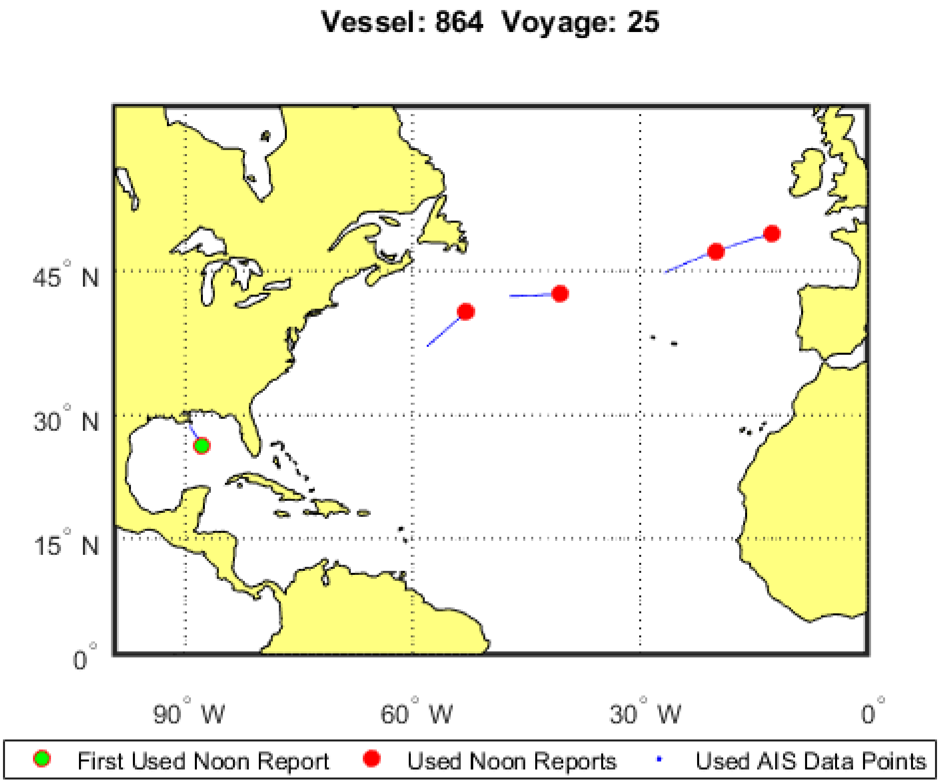
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
3	12	160	162	13.48	556.4	24.11	
9	24	323	295	12.30	620.2	24.95	
11	24	291	295	12.32	649.1	25.76	
14	23	305	305	13.28	570.0	24.94	
15	24	318	318	13.27	597.6	25.52	

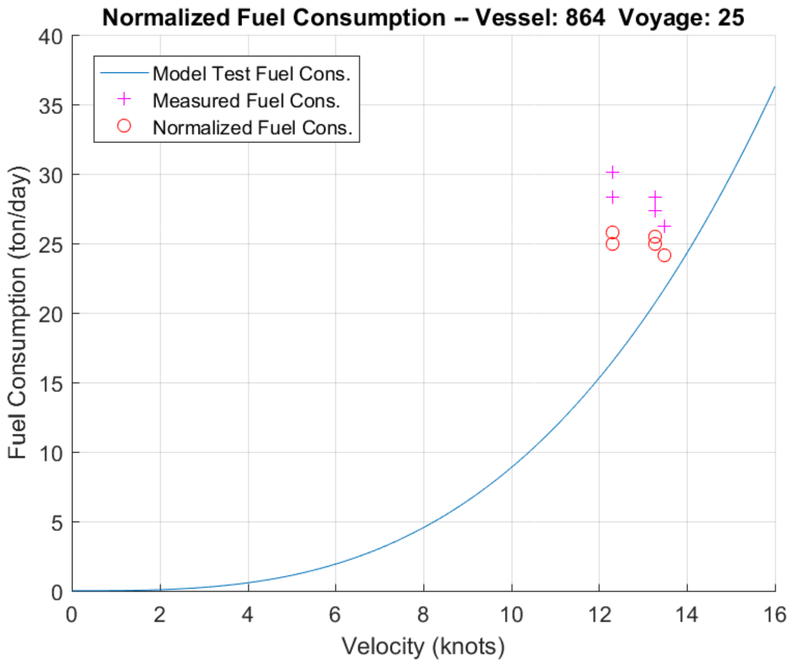
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 4 filtered out due to maneuvering.
Noon Report 5 filtered out due to maneuvering.
Noon Report 6 filtered out due to maneuvering.
Noon Report 7 filtered out due to maneuvering.
Noon Report 8 filtered out due to maneuvering.
Noon Report 10 filtered out due to maneuvering.
Noon Report 16 filtered out due to maneuvering.
Noon Report 17 filtered out due to maneuvering.
Noon Report 12 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



C Model 1 MATLAB Code

The following is the entire MATLAB script for Model 1 developed in this thesis. It was developed in MATLAB R2016b and may not work correctly in other MATLAB versions.

```
%APPLICATION OF AIS DATA IN VESSEL PERFORMANCE ANALYSIS
%MASTER THESIS - MODEL 1
%DEVELOPED BY DANIEL MANNHEIM

close all
clear
clc

%% % % INPUT DATA

    %Vessel and Voyage Information
    Vessel = '864';  %Input vessel number as characters between ...
        apostrophes
    voyage_name = '25';
    remNR = [0]; %Manual removal of noon reports.  Set to 0 for ...
        no manual removals, otherwise set to specified noon ...
        reports. If multiple, put spaces between numbers.

    %Filter Limits
    Draft_Range = 2; %Set plus/minus draft from model test ...
        condition for draft filter, in meters
    Speed_STD_max = 0.1; %Set maximum standard deviation of ...
        speed for acceleration filter, in m/s
    Heading_STD_max = 0.1; %Set maximum standard deviation of ...
        heading for maneuvering filter, in rad

    %Folder Locations
    working_dir = 'C:\Users\Dan\Google Drive\Thesis\Matlab\';  ...
        %working directory
    database_filename = 'C:\Users\Dan\Google ...
        Drive\Thesis\Matlab\shipdatabase.db'; %filename of ...
        database file
    hindcast_loc = 'E:\Hindcast\';  %Location of hindcast data ...
        folder


% % % Constants

    knots = 0.51444; %1 knot in m/s
    me_SFOC = 0.175; %main engine specific fuel oil consumption, ...
        kg/kWh
    ISO_LCV_HFO = 42.7;  %ISO Standard for Fuel Lower Calorific ...
        Value for HFO
    HFO_def = 40.3;  %HFO Standard LCV
    MDO_def = 42.2;  %MDO Standard LCV
    MGO_def = 42.2;  %MGO Standard LCV
```

```
    eta_trans = 0.98; %direct transmission efficiency
    g = 9.81; %m/s2 gravitational acceleration constant
    kyy = 0.25; %Non-dimensional lateral radius of gyration estimate

% % % Load NC Toolbox to read wave hindcast data

    cd('C:\Users\Dan\Documents\MATLAB')
    addpath(fullfile(matlabroot,'toolbox','nctoolbox-master',''))
    setup_nctoolbox;

% % % Load Database File

    dbfile = fullfile(database_filename);
    conn = sqlite(dbfile,'readonly');

%% % % Determine Draft Limits Depending on Ship Type

    sqlquery1 = horzcat('SELECT name FROM Ships where ...
        SL_vessel_id = ',Vessel);
    results1 = string(fetch(conn,sqlquery1));

    if strcmp(results1{1}(1:2),'MR')==1
        Tmean = 11;  %Draft during model tests
        Tmin = Tmean - Draft_Range;  %Minimum for draft filter
        Tmax = Tmean + Draft_Range;  %Maximum for draft filter
    elseif strcmp(results1{1}(1:2),'VL')==1
        Tmean = 20.5;
        Tmin = Tmean - Draft_Range;
        Tmax = Tmean + Draft_Range;
    end

   % % % Initial Command Window Outputs

    disp(horzcat('Vessel: ',Vessel,' Voyage: ',voyage_name))
    disp(' ')
    disp('Filters:')
    disp(horzcat('Draught Range: ',num2str(Tmin),' to ...
        ',num2str(Tmax),' meters'))
    disp(' ')

%% % % Extract Noon Report Data

    sqlquery2 = horzcat('SELECT distinct report_start_utc, ...
        report_end_utc, main_engine_hfo_consumption, ...
        main_engine_mdo_consumption, ...
        main_engine_mgo_consumption, distance_logged, ...
        distance_observed,(draught_fore + draught_aft)/2, ...
        report_lat, report_lon, lower_calorific_value_for_hfo, ...
        lower_calorific_value_for_mdo, ...
        lower_calorific_value_for_mgo, sea_state, ...
        waves_direction, wind_speed, wind_direction FROM ...
        SeaLoggerData where vessel_id = ',Vessel,' and ...
        voyagename = ''',voyage_name,''' order by ...
        report_start_utc');
```

```
    results2 = fetch(conn,sqlquery2);

    NoonRpt.report_start = cell2mat(results2(:,1));  %Start of ...
        noon report
    NoonRpt.report_start = ...
        datenum(NoonRpt.report_start,'yyyy-mm-dd HH:MM:SS');  ...
        %Convert Time Strings to Numbers for Matlab Use

    NoonRpt.report_end = cell2mat(results2(:,2));   %End of noon ...
        report
    NoonRpt.report_end = datenum(NoonRpt.report_end,'yyyy-mm-dd ...
        HH:MM:SS');  %Convert Time Strings to Numbers for Matlab Use

    %handle noon reports that start on half-hour by rounding ...
        down to nearest hour
    NoonRpt.report_start = floor(NoonRpt.report_start * 24) / 24;
    NoonRpt.report_end = floor(NoonRpt.report_end * 24) / 24;

    NoonRpt.HFO = cell2mat(results2(:,3));  %HFO Consumption
    NoonRpt.HFO = double(NoonRpt.HFO);  %Convert from Integers ...
        to Double Precision

    NoonRpt.MDO = cell2mat(results2(:,4));  %MDO Consumption
    NoonRpt.MDO = double(NoonRpt.MDO);  %Convert from Integers ...
        to Double Precision

    NoonRpt.MGO = cell2mat(results2(:,5));  %MGO Consumption
    NoonRpt.MGO = double(NoonRpt.MGO);  %Convert from Integers ...
        to Double Precision

    NoonRpt.distance_logged = cell2mat(results2(:,6));  ...
        %Distance logged since last noon report
    NoonRpt.distance_logged = double(NoonRpt.distance_logged);  ...
        %Convert from Integers to Double Precision

    NoonRpt.distance_observed = cell2mat(results2(:,7));  ...
        %Distance logged since last noon report
    NoonRpt.distance_observed = ...
        double(NoonRpt.distance_observed);  %Convert from ...
        Integers to Double Precision

    NoonRpt.Tm = cell2mat(results2(:,8));  %Average draft of ship
    NoonRpt.Tm = double(NoonRpt.Tm);  %Convert from Integers to ...
        Double Precision

    NoonRpt.lat = cell2mat(results2(:,9)); %Latitude of ship
    NoonRpt.lon = cell2mat(results2(:,10)); %Longitude of ship

    NoonRpt.LCV_HFO = cell2mat(results2(:,11));  %Reported HFO LCV

    NoonRpt.LCV_MDO = cell2mat(results2(:,12));  %Reported MDO LCV

    NoonRpt.LCV_MGO = cell2mat(results2(:,13));  %Reported MGO LCV

```

```
    NoonRpt.sea_state = cell2mat(results2(:,14));  %Sea State
    NoonRpt.sea_state = double(NoonRpt.sea_state);  %Convert ...
        from Integers to Double Precision

    NoonRpt.waves_dir = cell2mat(results2(:,15));  %Wave Direction
    NoonRpt.waves_dir = double(NoonRpt.waves_dir);  %Convert ...
        from Integers to Double Precision

    NoonRpt.wind_speed = cell2mat(results2(:,16));  %Wind Speed
    NoonRpt.wind_speed = double(NoonRpt.wind_speed);  %Convert ...
        from Integers to Double Precision

    NoonRpt.wind_dir = cell2mat(results2(:,17));  %Wind Direction
    NoonRpt.wind_dir = double(NoonRpt.wind_dir);  %Convert from ...
        Integers to Double Precision

    % % % Handle NA values - if data is missing, set column to zeros
    if ischar(NoonRpt.HFO) == 1 || isequal(NoonRpt.HFO,'')
        NoonRpt.HFO = zeros(length(NoonRpt.report_start),1);
    end

    if ischar(NoonRpt.MDO) == 1 || isequal(NoonRpt.MDO,'')
        NoonRpt.MDO = zeros(length(NoonRpt.report_start),1);
    end

    if ischar(NoonRpt.MGO) == 1 || isequal(NoonRpt.MGO,'')
        NoonRpt.MGO = zeros(length(NoonRpt.report_start),1);
    end

    if ischar(NoonRpt.LCV_HFO) == 1 || isequal(NoonRpt.LCV_HFO,'')
        NoonRpt.LCV_HFO = zeros(length(NoonRpt.HFO),1);
    end

    if ischar(NoonRpt.LCV_MDO) == 1 || isequal(NoonRpt.LCV_MDO,'')
        NoonRpt.LCV_MDO = zeros(length(NoonRpt.MDO),1);
    end

    if ischar(NoonRpt.LCV_MGO) == 1 || isequal(NoonRpt.LCV_MGO,'')
        NoonRpt.LCV_MGO = zeros(length(NoonRpt.MGO),1);
    end

    % % % If LCV values are not reported, use standard values
    for i = 1:length(NoonRpt.LCV_HFO)
        if NoonRpt.LCV_HFO(i) == 0
            NoonRpt.LCV_HFO(i) = HFO_def;
        end
    end

    for i = 1:length(NoonRpt.LCV_MDO)
        if NoonRpt.LCV_MDO(i) == 0
            NoonRpt.LCV_MDO(i) = MDO_def;
        end
    end

```

```
    for i = 1:length(NoonRpt.LCV_MGO)
        if NoonRpt.LCV_MGO(i) == 0
            NoonRpt.LCV_MGO(i) = MGO_def;
        end
    end

    %Calculate Noon Report Length
    NoonRpt.length = ( NoonRpt.report_end - NoonRpt.report_start ...
       ) * 24 ; %noon report length in hours

    %Calculate Average Speed Over Noon Report
    NoonRpt.speed = NoonRpt.distance_logged ./ NoonRpt.length * ...
       knots; %speed in m/s

%% % % Filter Noon Reports Based on Draft, Speed, and Manually

    % % % Create Raw Data Frame
    NoonRpt.frame = zeros(length(NoonRpt.report_start),15);
    NoonRpt.frame = [NoonRpt.report_start, NoonRpt.report_end, ...
       NoonRpt.length, NoonRpt.lat, NoonRpt.lon,...
        NoonRpt.distance_logged, NoonRpt.distance_observed, ...
           NoonRpt.speed, NoonRpt.Tm, NoonRpt.HFO, NoonRpt.MDO, ...
           NoonRpt.MGO, zeros(length(NoonRpt.report_start),1), ...
           NoonRpt.LCV_HFO, NoonRpt.LCV_MDO, NoonRpt.LCV_MGO, ...
           NoonRpt.sea_state, NoonRpt.waves_dir, ...
           NoonRpt.wind_speed, NoonRpt.wind_dir];

    for i = 1:length(NoonRpt.frame(:,1))
        NoonRpt.frame(i,13) = i;  %Noon report number
    end

    %Create filtered Data Frame
    NoonRpt.filtered = NoonRpt.frame;

    %Manually remove a specified noon report
    for i=1:length(remNR)
        if remNR(i) ≠ 0
            NoonRpt.filtered(remNR(i),:) = 0;
            disp(horzcat('Noon Report #',num2str(remNR(i)),' ...
               Filtered Out Manually'))
        end
    end

    %Only use noon reports where draft > draft_min and < draft_max
    NoonRpt.draftfilt = zeros(1,1);
    for i = 1:length(NoonRpt.filtered(:,1))
        if and(  NoonRpt.filtered(i,9) ≥ Tmin , ...
           NoonRpt.filtered(i,9) ≤ Tmax )
            NoonRpt.filtered(i,:) = NoonRpt.filtered(i,:);  ...
               %Copy data when draft is in range
        elseif all(NoonRpt.filtered(i,:) == 0)  %if all data is ...
           already zero
            %do nothing if Noon Report already filtered out
        else
```

```
            disp(horzcat('Noon Report ...
                #',num2str(NoonRpt.filtered(i,13)),' Filtered ...
                Out Due to Draft'))
            NoonRpt.draftfilt(i,1) = NoonRpt.filtered(i,13);  ...
                %Save NR numbers which have been filtered out ...
                due to draft
            NoonRpt.filtered(i,:) = 0;  %Set row of data to zero
        end
    end

    %Delete zeros from draft filtered NR numbers
    NoonRpt.draftfilt( ¬any(NoonRpt.draftfilt,2), : ) = [];

    %Use noon reports where fuel use is missing
    NoonRpt.fuelfilt = zeros(1,1);
    for i = 1:length(NoonRpt.filtered(:,1))
        if sum(NoonRpt.filtered(i,10:12)) > 0
            NoonRpt.filtered(i,:) = NoonRpt.filtered(i,:);  ...
                %Copy data when fuel data exists
        elseif all(NoonRpt.filtered(i,:) == 0)  %if all data is ...
            already zero
            %do nothing if Noon Report already filtered out
        else
            disp(horzcat('Noon Report ...
                #',num2str(NoonRpt.filtered(i,13)),' Filtered ...
                Out Due to Fuel Use'))
            NoonRpt.fuelfilt(i,1) = NoonRpt.filtered(i,13);  ...
                %Save NR numbers which have been filtered out ...
                due to draft
            NoonRpt.filtered(i,:) = 0;  %Set row of data to zero
        end
    end

    %Delete zeros from fuel filtered NR numbers
    NoonRpt.fuelfilt( ¬any(NoonRpt.fuelfilt,2), : ) = [];  %

    %Number of remaining NRs
    NRcount = length(NoonRpt.frame(:,1));  %Total Number of Noon ...
        Reports
    NRindices = NoonRpt.filtered(:,13);  %Noon Reports numbers used


%% % %Extracting AIS Data from Database

    sqlquery3 = horzcat('SELECT distinct start, end, lat_mean, ...
        lon_mean, air_temperature, draught_aft, draught_fore, ...
        hdt_mean, sog_mean, hdt_min, hdt_max, sog_min, sog_max, ...
        sog_std, hdt_std FROM SeaLoggerData where vessel_id = ...
        ',Vessel,' and voyagename = ''',voyage_name,''' order by ...
        report_start_utc');
    results3 = fetch(conn,sqlquery3);

    %Delete cell rows which are missing necessary data
    results3(any(cellfun(@isempty,results3),2), : ) = [];
```

```

    %Pull Out Data from SQL Query
    AIS.start = cell2mat(results3(:,1));  %Start time of AIS period
    AIS.end = cell2mat(results3(:,2));  %End time of AIS period


    %For the following data, the database entries have different ...
        data
    %types.  The process used is:  1) Assume data is string, and ...
        convert to
    %double.  2) If output data is double, then the process ...
        worked.  Else,
    %if the output is NaN, then input data must have been a ...
        cell.  3)
    %Convert from cell to double.

        %Latitude
        AIS.lat = str2double(results3(:,3));
        for i = 1:length(AIS.lat)
            if isnan(AIS.lat(i)) == 1
                AIS.lat(i) = cell2mat(results3(i,3));
            end
        end

        %Longitude
        AIS.lon = str2double(results3(:,4));
        for i = 1:length(AIS.lon)
            if isnan(AIS.lon(i)) == 1
                AIS.lon(i) = cell2mat(results3(i,4));
            end
        end

        %Air Temperature from Noon Report
        AIS.airt_nr = str2double(results3(:,5));
        for i = 1:length(AIS.airt_nr)
            if isnan(AIS.airt_nr(i)) == 1
                AIS.airt_nr(i) = cell2mat(results3(i,5));
            end
        end

        %Mean Draft from Noon Report
        AIS.Tm = ( str2double(results3(:,6)) + ...
            str2double(results3(:,7)) ) / 2;
        for i = 1:length(AIS.Tm)
            if isnan(AIS.Tm(i)) == 1
                AIS.Tm(i) = ( cell2mat(results3(i,6)) + ...
                    cell2mat(results3(i,7)) ) / 2;
            end
        end

        %Mean Heading Angle
        AIS.hdt_mean = str2double(results3(:,8));
        for i = 1:length(AIS.hdt_mean)
            if isnan(AIS.hdt_mean(i)) == 1
```

```
                AIS.hdt_mean(i) = cell2mat(results3(i,8));
            end
        end

        %Minimum Heading Angle
        AIS.hdt_min = str2double(results3(:,10));
        for i = 1:length(AIS.hdt_min)
            if isnan(AIS.hdt_min(i)) == 1
                AIS.hdt_min(i) = cell2mat(results3(i,10));
            end
        end

        %Maximum Heading Angle
        AIS.hdt_max = str2double(results3(:,11));
        for i = 1:length(AIS.hdt_max)
            if isnan(AIS.hdt_max(i)) == 1
                AIS.hdt_max(i) = cell2mat(results3(i,11));
            end
        end

        %Standard Deviation of Heading
        AIS.hdt_std = str2double(results3(:,15));
        for i = 1:length(AIS.hdt_std)
            if isnan(AIS.hdt_std(i)) == 1
                AIS.hdt_std(i) = cell2mat(results3(i,15));
            end
        end

        %Mean Speed Over Ground
        AIS.sog_mean = str2double(results3(:,9));
        for i = 1:length(AIS.sog_mean)
            if isnan(AIS.sog_mean(i)) == 1
                AIS.sog_mean(i) = cell2mat(results3(i,9));
            end
        end

        %Minimum Speed Over Ground
        AIS.sog_min = str2double(results3(:,12));
        for i = 1:length(AIS.sog_min)
            if isnan(AIS.sog_min(i)) == 1
                AIS.sog_min(i) = cell2mat(results3(i,12));
            end
        end

        %Maximum Speed Over Ground
        AIS.sog_max = str2double(results3(:,13));
        for i = 1:length(AIS.sog_max)
            if isnan(AIS.sog_max(i)) == 1
                AIS.sog_max(i) = cell2mat(results3(i,13));
            end
        end

        %Standard Deviation of Speed Over Ground
        AIS.sog_std = str2double(results3(:,14));
```

```
        for i = 1:length(AIS.sog_std)
            if isnan(AIS.sog_std(i)) == 1
                AIS.sog_std(i) = cell2mat(results3(i,14));
            end
        end

    %Convert Date Time Strings to Serial Numbers for Matlab Use
    AIS.start = datenum(AIS.start,'yyyy-mm-dd HH:MM:SS');
    AIS.end = datenum(AIS.end,'yyyy-mm-dd HH:MM:SS');

    %Correct Heading Values to be between 0 and 2Pi
    for i=1:length(AIS.hdt_mean)
        if AIS.hdt_mean(i) < 0
            AIS.hdt_mean(i) = AIS.hdt_mean(i) + 2*pi;
        end
    end

%% % %Create AIS Data Frame and Extract Only Times Relevant to ...
   NRs, and Filter Due to Maneuvering, Acceleration, and ...
   Missing Data

    % % % Create Raw Data Frame

     AIS.frame = [round(24*60*AIS.start)/24/60, ...
        round(24*60*AIS.end)/24/60, AIS.lat, AIS.lon,...
                 AIS.airt_nr, AIS.Tm, AIS.hdt_mean, ...
                    AIS.sog_mean, AIS.hdt_min, AIS.hdt_max, ...
                    AIS.sog_min, AIS.sog_max, AIS.sog_std, ...
                    AIS.hdt_std];

    %Sort Data Based on Timestamp
    AIS.frame = sortrows(AIS.frame,1);

    %If AIS ending time is before AIS starting time ...
       accidentally, Set row
    %to zeros
    for i = 1:size(AIS.frame,1)
        if AIS.frame(i,2) < AIS.frame(i,1)
            AIS.frame(i,:) = 0;
        end
    end

    %Generate Variable Names for Each NR
    for i = 1:NRcount
        S{i} = horzcat(num2str(i));
    end
    NR = matlab.lang.makeValidName(S);

    %Initialize Matrices and Counter for Filtering
    AIS.datafilt(1,1) = 0;  %NRs filtered for bad/missing AIS data
    AIS.accelfilt(1,1) = 0;  %NRs filtered for acceleration
    AIS.accelcount = 1;  %Counter for acceleration filter
    AIS.maneuvfilt(1,1) = 0;  %NRs filtered for maneuvering
    AIS.maneuvcount = 1;  %Counter for maneuvering filter
```

```

    %Extract Data Associated with Each NR
    for j = 1:NRcount     %For Each Noon Report
        if ismember(j,NRindices) %Only Extract Data for NRs used ...
            determined above
            AIS.NR{j,1}.data(1,:) = ones(1,size(AIS.frame,2));  ...
                %Set first row to ones - needed to eliminate ...
                possibility of zero matrix
            for i = 1:size(AIS.frame,1)     %Check Each Row of ...
                AIS Data Frame
                if AIS.frame(i,1) ≥ NoonRpt.filtered(j,1) && ...
                    AIS.frame(i,2) ≤ NoonRpt.filtered(j,2)  %If ...
                    AIS start/end time is between NR start/end times
                    AIS.NR{j,1}.data(i+1,:) = AIS.frame(i,:);  ...
                        %Copy data into next row
                end
            end

            %Handle Rows with Missing Data
            for i = 1:size(AIS.NR{j}.data,1)
                if AIS.NR{j}.data(i,3) == 0 && ...
                    AIS.NR{j}.data(i,4) == 0 && ...
                    AIS.NR{j}.data(i,7) == 0  %If Latitude, ...
                    Longitude, and Heading = 0 -- means bad data
                    AIS.NR{j}.data(i,:)=0; %Delete row if Lat, ...
                        Lon, and Heading = Z0
                end
            end
            %delete zero rows in filtered data
            AIS.NR{j}.data( ¬any(AIS.NR{j}.data,2), : ) = [];

            %Filter Due to Acceleration
            for i = 2:size(AIS.NR{j}.data,1)
                if AIS.NR{j}.data(i,13) > Speed_STD_max  %Filter ...
                    out if SOG standard deviation > 0.07 - ...
                    indicates acceleration
                    AIS.NR{j}.data(i,:)=0;  %If acceleration ...
                        occurs, set row to zeros
                    AIS.accelfilt(AIS.accelcount,1) = j;  %Save ...
                        Noon Report Number
                    AIS.accelcount = AIS.accelcount + 1;  %Add ...
                        to acceleration filter count
                end
            end
            %delete zero rows in filtered data
            AIS.NR{j}.data( ¬any(AIS.NR{j}.data,2), : ) = [];

            %Filter Due to Maneuvering
            if ismember(j,AIS.accelfilt)  %Skip NR if already ...
                filtered from acceleration
                %do nothing
            else
                for i = 2:size(AIS.NR{j}.data,1)
                    if AIS.NR{j}.data(i,14) > Heading_STD_max  ...
```

```
                        %Filter out if heading standard ...
                        deviation > 0.1 - indicates maneuvering
                        AIS.NR{j}.data(i,:) = 0;
                        AIS.maneuvfilt(AIS.maneuvcount,1) = j;  ...
                            %Save Noon Report Number
                        AIS.maneuvcount = AIS.maneuvcount + 1;  ...
                            %Add to maneuvering filter count
                    end
                end
            end
            AIS.NR{j}.data( ¬any(AIS.NR{j}.data,2), : ) = [];  ...
                %delete blank rows

            %Check if valid data still exists
            if size(AIS.NR{j}.data,1) ≤ 2  %If only row ...
                remaining is the row of ones added initially
                disp(horzcat('Noon Report ...
                    #',num2str(NoonRpt.filtered(j,13)),' ...
                    Filtered Out Due Lack of AIS Data.'))
                AIS.datafilt(j,1) = NoonRpt.filtered(j,13);  ...
                    %Save NR numbers which have been filtered ...
                    out due to draft
                NRindices(j) = 0;  %skip NR in future
                %delete all data for specified noon report
                AIS.NR{j}.data(:,:)=[];
            else  %if data still exists
                %delete first row of ones only
                AIS.NR{j}.data(1,:)=[];
            end
        end
    end

    %delete zero rows in NR filtered numbers
    AIS.datafilt( ¬any(AIS.datafilt,2), : ) = [];
    AIS.accelfilt( ¬any(AIS.accelfilt,2), : ) = [];
    AIS.maneuvfilt( ¬any(AIS.maneuvfilt,2), : ) = [];
    if size(AIS.accelfilt,1) > 0
        AIS.accelfilt = unique(AIS.accelfilt);
        for i=1:size(AIS.accelfilt)
            disp(horzcat('Noon Report ...
                #',num2str(AIS.accelfilt(i)),' Filtered Out Due ...
                to Acceleration.'))
            NRindices(AIS.accelfilt(i)) = 0; %Skip NR in the future
        end
    end
    if size(AIS.maneuvfilt,1) > 0
        AIS.maneuvfilt = unique(AIS.maneuvfilt);
        for i=1:size(AIS.maneuvfilt)
            disp(horzcat('Noon Report ...
                #',num2str(AIS.maneuvfilt(i)),' Filtered Out Due ...
                to Maneuvering.'))
            NRindices(AIS.maneuvfilt(i)) = 0; %Skip NR in the future
        end
    end
```

```

%% % %Filter if AIS Length does not equal Noon Report Length, ...
    and Output NR Data

    for j = 1:NRcount
        if ismember(j,NRindices)  %only perform for NRs not ...
            filtered out
            %calculate sum duration of AIS reports and compare ...
                to NR length
            for i = 1:length(AIS.NR{j}.data(:,1))
                AIS.NR{j}.durcompare(i,1) = (AIS.NR{j}.data(i,2) ...
                    - AIS.NR{j}.data(i,1))*24;  %time of each ...
                    AIS periodin hours;
            end
            if round( sum(AIS.NR{j}.durcompare), 0 ) ≠ round( ...
                NoonRpt.filtered(j,3) , 0 ) || round( ...
                (AIS.NR{j}.data(end,2)-AIS.NR{j}.data(1,1))*24, ...
                0 ) ≠ round( NoonRpt.filtered(j,3) , 0 )  %If ...
                durations do not equal
                NRindices(j) = 0; %Set NR index to zero to skip ...
                    row in future
                AIS.durfilt(j,1) = j;  %Save filtered NR number ...
                    for output
                disp(horzcat('Noon Report ...
                    #',num2str(NoonRpt.filtered(j,13)),' ...
                    Filtered Out Due to Inconsistent AIS/NR ...
                    Lengths.'))
            end
        end
    end
    %delete zero rows in duration filter matrix
    AIS.durfilt( ¬any(AIS.durfilt,2), : ) = [];

   %create table array for output
    for j = 1:NRcount
        if ismember(j,NRindices)  %Only Perform Calcs for ...
            NRindices determined above
            NoonRpt.outputarray1(j,1) = NoonRpt.filtered(j,13); ...
                %noon report number
            NoonRpt.outputarray1(j,2) = NoonRpt.filtered(j,3); ...
                %nr length
            NoonRpt.outputarray1(j,3) = NoonRpt.filtered(j,9);%Draft
            NoonRpt.outputarray1(j,4) = NoonRpt.filtered(j,10); ...
                %HFO (ton)
            NoonRpt.outputarray1(j,5) = NoonRpt.filtered(j,11);  ...
                %MDO (ton)
            NoonRpt.outputarray1(j,6) = NoonRpt.filtered(j,12);  ...
                %MGO (ton)
            NoonRpt.outputarray1(j,7) = ...
                round(NoonRpt.filtered(j,14),2); %HFO LCV
            NoonRpt.outputarray1(j,8) = ...
                round(NoonRpt.filtered(j,15),2);  %MDO LCV
            NoonRpt.outputarray1(j,9) = ...
                round(NoonRpt.filtered(j,16),2);  %MGO LCV
```

```
        end
    end
    %delete zero rows in output table
    NoonRpt.outputarray1( ¬any(NoonRpt.outputarray1,2), : ) = ...
       []; %rows

    %Output table
    NoonRpt.table1 = ...
       array2table(NoonRpt.outputarray1,'VariableNames',{'NR', ...
       'Length', 'Draft', 'HFO', 'MDO', 'MGO', 'HFO_LCV', ...
       'MDO_LCV', 'MGO_LCV'});

    %Show start and end dates/time of noon reports
    NoonRpt.dates(1,:) = 'NR Start              NR End ...
                 ';
    for i = 1:length(NoonRpt.filtered(:,1))
        if ismember(i,NRindices)
            NoonRpt.dates(i+1,:) = ...
               horzcat(datestr(NoonRpt.filtered(i,1),'dd mmm ...
               yyyy HH:MM:SS'),'    ...
               ',datestr(NoonRpt.filtered(i,2),'dd mmm yyyy ...
               HH:MM:SS'));
            NoonRpt.dates2(i,1) = (NoonRpt.filtered(i,1));
            NoonRpt.dates2(i,2) = (NoonRpt.filtered(i,2))';
        end
    end
    NoonRpt.dates( ¬any(NoonRpt.dates,2), : ) = []; %delete ...
       zero rows
    NoonRpt.dates2( ¬any(NoonRpt.dates2,2), : ) = []; %delete ...
       zero rows
    disp(' ')
    disp(' ')
    disp(horzcat('Data for the ...
       ',num2str(size(NoonRpt.outputarray1,1)),' noon reports ...
       used in the analysis are shown below.'))
    disp(' ')
    disp(NoonRpt.dates)
    disp(' ')
    disp(NoonRpt.table1)

%% % %Extract Resistance, Powering, Open Water, Self Propulsion, ...
    Vessel Particulars Data from Database

    % % % Effective Power Curves
        sqlquery4 = horzcat('SELECT x,y,(TF+TA)/2,nabla,TPM,S ...
           FROM ships inner join model_test_data on ...
           Ships.model_test_data_id = model_test_data.ID inner ...
           join model_condition on model_test_data.ID = ...
           model_condition.model_test_data_id inner join ...
           Curve_points on model_condition.PE_curve_id = ...
           Curve_points.Curve_id where SL_vessel_id = ',Vessel);
        results4 = fetch(conn,sqlquery4);
        PE.V = cell2mat(results4(:,1)); %Velocity
        PE.P = cell2mat(results4(:,2)); %Effective Power
```

```
        PE.Tm = cell2mat(results4(1,3));  %Mean Draft During ...
           Model Test
        PE.nabla = cell2mat(results4(1,4));  %Displacement ...
           During Model Test
        PE.TPM = cell2mat(results4(1,5));  %Tons per Meter Immersion
        PE.S = cell2mat(results4(1,6));  %Surface Area of Hull

        %PE Curve Fit
        [xData, yData] = prepareCurveData( PE.V, PE.P );
        % Set up fittype and options.
        ft = fittype( 'poly3' );
        opts = fitoptions( 'Method', 'LinearLeastSquares' );
        opts.Lower = [0 0 0 0];
        opts.Upper = [Inf 0 0 0];
        % Fit model to data.
        [PEfitresult, gof] = fit( xData, yData, ft, opts );  ...
           %Curve Fit for PE

        %Convert PE to Resistance
        R.V = PE.V;  %Velocity
        R.R = PE.P ./ R.V;  %Hull Resistance
        if isnan(R.R(1)) == 1  %If first entry is Nan due to ...
           division by zero
           R.R(1) = 0;  %Set first entry to zero
        end
        %For MR, need to force R to start at zero.
        if strcmp(results1{1}(1:2),'MR')==1
            R.R(end+1) = 0;
            R.V(end+1) = 0;
            R.R = sort(R.R);
            R.V = sort(R.V);
        end

        %Resistance Curve Fit
        [xData, yData] = prepareCurveData( R.V, R.R );
        % Set up fittype and options.
        ft = fittype( 'poly2' );
        opts = fitoptions( 'Method', 'LinearLeastSquares' );
        opts.Lower = [0 0 0];
        opts.Upper = [Inf 0 0];
        % Fit model to data.
        [Rfitresult, gof] = fit( xData, yData, ft, opts );  ...
           %Hull Resistance Curve Fit

    % % % Self Propulsion Curves
        sqlquery5 = horzcat('SELECT V, t, w, eta_RR, eta_hull ...
           from ships inner join model_test_data on ...
           Ships.model_test_data_id = model_test_data.ID inner ...
           join model_condition on model_test_data.ID = ...
           model_condition.model_test_data_id inner join ...
           SP_curves on model_condition.SP_curve_id = ...
           SP_curves.Curve_id where SL_vessel_id = ',Vessel);
        results5 = fetch(conn,sqlquery5);
        SP.V = cell2mat(results5(:,1));  %Velocity
```

```
        SP.t = cell2mat(results5(:,2));  %Thrust Deduction
        SP.w = cell2mat(results5(:,3));  %Wake Fraction
        SP.eta_RR = cell2mat(results5(:,4));  %Relative Rotative ...
            Efficiency
        SP.eta_hull = cell2mat(results5(:,5));  %Hull Efficiency
        SP.V_polyfit = 0:1*knots:18*knots;  %Set range of velocities
        SP.eta_RR_polyfit = spline(SP.V,SP.eta_RR,SP.V_polyfit); ...
             %Curve fit for relative rotative efficiency
        SP.eta_hull_polyfit = ...
            spline(SP.V,SP.eta_hull,SP.V_polyfit);  %Curve fit ...
            for hull efficiency

    % % % Propeller Diameter
        sqlquery6 = horzcat('SELECT D from ships inner join ...
            model_test_data on Ships.model_test_data_id = ...
            model_test_data.ID inner join open_water_data on ...
            model_test_data.open_water_data_ID = ...
            open_water_data.ID where SL_vessel_id = ',Vessel);
        results6 = fetch(conn,sqlquery6);
        D = cell2mat(results6(:,1));  %Propeller Diameter

    % % % Delivered Power
        sqlquery7 = horzcat('SELECT x, y from ships inner join ...
            model_test_data on Ships.model_test_data_id = ...
            model_test_data.ID inner join model_condition on ...
            model_test_data.ID = ...
            model_condition.model_test_data_id inner join ...
            Curve_points on model_condition.PD_curve_id = ...
            Curve_points.Curve_id where SL_vessel_id = ',Vessel);
        results7 = fetch(conn,sqlquery7);
        PD.V = cell2mat(results7(:,1));  %Velocity
        PD.P = cell2mat(results7(:,2));  %Delivered Power
        PD.V(end+1) = 0; %Manually add in zero velocity starting ...
            point for curve fit
        PD.P(end+1) = 0; %Manually add in zero power starting ...
            point for curve fit

        %PD Curve Fit
        [xData, yData] = prepareCurveData( PD.V, PD.P );
        % Set up fittype and options.
        ft = fittype( 'poly3' );
        opts = fitoptions( 'Method', 'LinearLeastSquares' );
        opts.Lower = [0 0 0 0];
        opts.Upper = [Inf 0 0 0];
        % Fit model to data.
        [PDfitresult, gof] = fit( xData, yData, ft, opts );  ...
            %Delivered Power Curve Fit

    % % % Front area of the vessel and Wind Coefficients

        sqlquery8 = horzcat('SELECT area_front from ships inner ...
            join model_test_data on Ships.model_test_data_id = ...
            model_test_data.ID inner join model_condition on ...
            model_test_data.ID = ...
```

```
            model_condition.model_test_data_id where ...
            SL_vessel_id = ',Vessel);
        results8 = fetch(conn,sqlquery8);
        CXdata.A_F = cell2mat(results8(:,1));  %Frontal Area of Ship

        sqlquery9 = horzcat('SELECT angle, coef from ships inner ...
            join model_test_data on Ships.model_test_data_id = ...
            model_test_data.ID inner join model_condition on ...
            model_test_data.ID = ...
            model_condition.model_test_data_id inner join ...
            wind_coef on model_condition.wind_cx_id = ...
            wind_coef.Curve_id where SL_vessel_id = ',Vessel);
        results9 = fetch(conn,sqlquery9);
        CXdata.angle = cell2mat(results9(:,1));  %Angles for ...
            Wind Coefficients
        CXdata.coef = cell2mat(results9(:,2));   %Wind Coefficients

    % % % Vessel Particulars
        sqlquery10 = horzcat('SELECT length, breadth, CB from ...
            ships where SL_vessel_id = ',Vessel);
        results10 = fetch(conn,sqlquery10);

        ves.length = cell2mat(results10(:,1));  %Length of ship
        ves.breadth = cell2mat(results10(:,2));  %Beam of Ship
        ves.CB = cell2mat(results10(:,3));  %Block coefficient ...
            of ship

    % % %Close connection to database
    close(conn);



%% % %Start Performing Calculations

    addpath(genpath(hindcast_loc))  %Location of Files

    %Calculate Number of Nonzero Indices
        nonzero = nnz(NRindices);  %total number of remaining NRs
        count = 0;  %initializing counter for status update

    %Only Perform For NR Sets not Filtered Out
    for j = 1:NRcount
        if ismember(j,NRindices)  %Only Perform Calcs for ...
            NRindices determined above

        %Status Update
        count = count + 1;  %Add to counter after each iteration
        disp(horzcat('NR ',num2str(j),'... ...
            (',num2str(count),'/',num2str(nonzero),')'))

 %% Speed Through Water Calculation

        disp(horzcat('Performing Speed Through Water ...
            Calculations...'))
```

```

        %Determine Duration and Distance Between Two Subsequent ...
            Readings

        %Duration of each AIS data point
        for i = 1:length(AIS.NR{j}.data(:,1))
            AIS.NR{j}.dur(i,1) = ( AIS.NR{j}.data(i,2) - ...
                AIS.NR{j}.data(i,1) )*24;  %time in hours
        end

        %Speed Between Locations in m/s without current
        AIS.NR{j}.sog = AIS.NR{j}.data(:,8) ;

        %Midpoint of Time For Each Period
        for i = 1:length(AIS.NR{j}.data(:,1))
            AIS.NR{j}.avgtime(i,1) = ...
                (AIS.NR{j}.data(i,1)+AIS.NR{j}.data(i,2))/2;
        end

        %Average Location For Each Period
        for i = 1:length(AIS.NR{j}.data(:,1))
            AIS.NR{j}.avglat(i,1) = (AIS.NR{j}.data(i,3));
            AIS.NR{j}.avglon(i,1) = (AIS.NR{j}.data(i,4));
        end

        %Average Drafts for Each Period
        AIS.NR{j}.Tm = AIS.NR{j}.data(:,6);  %Drafts

        %Create Zero Matrices
        AIS.NR{j}.curs = zeros(length(AIS.NR{j}.data(:,1)),1);
        AIS.NR{j}.curd = zeros(length(AIS.NR{j}.data(:,1)),1);

        %Find Current Data for each location/time
        for i = 1:length(AIS.NR{j}.data(:,1))
            date = AIS.NR{j}.avgtime(i);
            currentlat = AIS.NR{j}.avglat(i);
            currentlon = wrapTo360(AIS.NR{j}.avglon(i));

            %Convert AIS times into vector to create strings
            datevector = datevec(datestr(date));

            % % % CURRENTS

            % Find Correct File for Current Data
            filenamestring = horzcat(hindcast_loc, 'CTS\', ...
                num2str(datevector(1)), '\', ...
                sprintf('%02d',datevector(2)), '\', ...
                'metoffice_glosea_orca025_GL4_RFVL_*dm', ...
                num2str(datevector(1)), sprintf('%02d', ...
                datevector(2)), sprintf('%02d', datevector(3)), ...
                '.nc');
            filename = dir(filenamestring);
            filename = filename.name;

```

```
            %Pull Out Current Data
            lon = ncread(filename,'lon');
            lat = ncread(filename,'lat');
            currentu = ncread(filename,'vozocrtx');  %Eastward ...
                Sea Water Velocity
            currentv = ncread(filename,'vomecrty'); %Northward ...
                Sea Water Velocity

            [¬, latindex] = min(abs(currentlat - lat));
            [¬ ,lonindex] = min(abs(currentlon - lon));

            currentu = currentu(lonindex,latindex,1,1);
            currentv = currentv(lonindex,latindex,1,1);

            AIS.NR{j}.curs(i,1) = sqrt(currentu^2 + currentv^2);
            AIS.NR{j}.curd(i,1) = wrapTo2Pi(pi/2 - ...
                atan2(currentv,currentu));  %% atan2 has 0 at ...
                east direction, so have to correct to be in same ...
                orientation as headings

        end

        %Current Speed at Each Location in Direction of Travel
        AIS.NR{j}.curs_dir = -AIS.NR{j}.curs .* cos( ...
            AIS.NR{j}.curd - AIS.NR{j}.data(:,7) );

        %Speed Between Locations with Currents
        AIS.NR{j}.stw = AIS.NR{j}.sog + AIS.NR{j}.curs_dir;

        %Distance Traveled
        AIS.NR{j}.dist = AIS.NR{j}.dur .* AIS.NR{j}.stw * 60 * ...
            60;  %Observed in meters
        AIS.NR{j}.dist1 = AIS.NR{j}.sog .* AIS.NR{j}.dur / ...
            knots;  %Logged in NM

%% Determine Water Properties

        disp(horzcat('Determining Water Properties...'))

        for i = 1:length(AIS.NR{j}.stw)

            date = AIS.NR{j}.avgtime(i);
            currentlat = AIS.NR{j}.avglat(i);
            currentlon = wrapTo360(AIS.NR{j}.avglon(i));

            %Convert AIS times into vector to create strings
            datevector = datevec(datestr(date));

            % % % TEMPERATURE

            % Find Correct File for Temperature Data
            filenamestring = horzcat(hindcast_loc,'CTS\', ...
                num2str(datevector(1)), '\', sprintf('%02d', ...
                datevector(2)), ...
```

```
'\','metoffice_glosea_orca025_GL4_TEMP_*dm', ...
num2str(datevector(1)), sprintf('%02d', ...
datevector(2)), sprintf('%02d', datevector(3)), ...
'.nc');
filename = dir(filenamestring);
filename = filename.name;

%Pull Out Temperature Data
lon = ncread(filename,'lon');
lat = ncread(filename,'lat');
temp = ncread(filename,'votemper') - 273.15;  ...
    %Seawater Temperature in C

[¬, latindex] = min(abs(currentlat - lat));
[¬ ,lonindex] = min(abs(currentlon - lon));

AIS.NR{j}.temp(i,1) = temp(lonindex,latindex,1,1);  ...
    %Water temperature

% % % SALINITY

% Find Correct File for Salinity Data
filenamestring = horzcat(hindcast_loc,'CTS\', ...
    num2str(datevector(1)), '\', sprintf('%02d', ...
    datevector(2)), '\', ...
    'metoffice_glosea_orca025_GL4_PSAL_*dm', ...
    num2str(datevector(1)), sprintf('%02d', ...
    datevector(2)), sprintf('%02d', datevector(3)), ...
    '.nc');
filename = dir(filenamestring);
filename = filename.name;

%Pull Out Salinity Data
lon = ncread(filename,'lon');
lat = ncread(filename,'lat');
salin = ncread(filename,'vosaline');  %Salinity, ...
    'PSU [g/kg]'

[¬, latindex] = min(abs(currentlat - lat));
[¬ ,lonindex] = min(abs(currentlon - lon));

AIS.NR{j}.salin.PSU(i,1) = ...
    salin(lonindex,latindex,1,1);  %Water Salinity ...
    in gm/kg

end   %end calculation for each AIS time/location

%Convering salinity from PSU to PPM
AIS.NR{j}.salin.PPM = AIS.NR{j}.salin.PSU * 1.004715 * ...
    1000;  %Water Salinity in Parts Per Million

% % % Calculate Seawater Density

% El-Dessouky, Ettouny (2002) A.1
```

```
        rho.B = ( (2) .* (AIS.NR{j}.salin.PPM) ./ 1000 - 150 ) ...
            ./ 150;
        rho.G1 = 0.5;
        rho.G2 = rho.B;
        rho.G3 = 2 * rho.B.^2 - 1;
        rho.A1 = 4.032219 .* rho.G1 + 0.115313 .* rho.G2 + ...
            3.26e-4 .* rho.G3;
        rho.A2 = -0.108119 .* rho.G1 + 1.571e-3 .* rho.G2 - ...
            4.233e-4 .* rho.G3;
        rho.A3 = -0.012247 .* rho.G1 + 1.74e-3 .* rho.G2 - 9e-6 ...
            .* rho.G3;
        rho.A4 = 6.92e-4 .* rho.G1 - 8.7e-5 .* rho.G2 - 5.3e-5 ...
            .* rho.G3;
        rho.A = ( (2) .* (AIS.NR{j}.temp) - 200 )./160;
        rho.F1 = 0.5;
        rho.F2 = rho.A;
        rho.F3 = 2 .* rho.A.^2 - 1;
        rho.F4 = 4 .* rho.A.^3 - 3.*rho.A;
        AIS.NR{j}.rho_w = 10^3 .* (rho.A1 .* rho.F1 + rho.A2 .* ...
            rho.F2 + rho.A3 .* rho.F3 + rho.A4 .* rho.F4);  ...
            %Water density

        % % % Calculate Seawater Kinematic Viscosity

        % El-Dessouky, Ettouny (2002) A.3
        visc.A = 1.474e-3 + 1.5e-5 .* AIS.NR{j}.temp - 3.927e-8 ...
            .* AIS.NR{j}.temp.^2;
        visc.B = 1.0734e-5 - 8.5e-8 .* AIS.NR{j}.temp + 2.23e-10 ...
            .* AIS.NR{j}.temp.^2;
        visc.mu_R = 1 + visc.A .* AIS.NR{j}.salin.PSU + visc.B ...
            .* AIS.NR{j}.salin.PSU.^2;
        visc.mu_W = exp( -3.79418 + 604.129 ./ (139.18 + ...
            AIS.NR{j}.temp ) );
        visc.mu = visc.mu_W .* visc.mu_R .* 10^-3;
        AIS.NR{j}.nu = visc.mu ./ AIS.NR{j}.rho_w;  %Water ...
            Kinematic Viscosity

%% Wave Added Resistance


           disp(horzcat('Performing Wave Added Resistance ...
               Calculations...'))

           %Initializing Zero Matrices
            AIS.NR{j}.waved = zeros(length(AIS.NR{j}.stw),1);
            AIS.NR{j}.Hs= zeros(length(AIS.NR{j}.stw),1);
            AIS.NR{j}.waveT = zeros(length(AIS.NR{j}.stw),1);

            % % % WAVE DATA

            for i = 1:length(AIS.NR{j}.stw)
                date = AIS.NR{j}.avgtime(i);
                currentlat = AIS.NR{j}.avglat(i);
                currentlon = wrapTo360(AIS.NR{j}.avglon(i));
```

```

            %Convert AIS times into vector to create strings
            datevector = datevec(datestr(date));

            %Creating Strings for Reading Wave Data
            gribdp = horzcat('multi_1.glo_30m.dp.', ...
                num2str(datevector(1)), sprintf('%02d', ...
                datevector(2)), '.grb2');  %Direction
            gribhs = horzcat('multi_1.glo_30m.hs.', ...
                num2str(datevector(1)), sprintf('%02d', ...
                datevector(2)), '.grb2');  %Sig Wave Height
            gribtp = horzcat('multi_1.glo_30m.tp.', ...
                num2str(datevector(1)), sprintf('%02d', ...
                datevector(2)), '.grb2');  %Wave Period

            %Reading Wave Data
            ncodp = ncgeodataset(gribdp);  %Wave Direction
            ncohs = ncgeodataset(gribhs);  %Wave Height
            ncotp = ncgeodataset(gribtp);  %Wave Period

            lat=ncodp{'lat'}(:);
            lon=ncodp{'lon'}(:);
            time=ncodp{'time'}(:);

            [¬, latindex] = min(abs(lat - currentlat));
            [¬, lonindex] = min(abs(lon - currentlon));
            [¬, timeindex] = min(abs(time - ( ...
                (datevector(3)-1)*24+datevector(4) )));

            %Reading Values at position and time of interest
            AIS.NR{j}.Hs(i,1) = ...
                ncohs{'Significant_height_of_combined',...
                 '_wind_waves_and_swell_surface'}...
                 (timeindex,latindex,lonindex);  %Significant ...
                    wave height
            AIS.NR{j}.waveT(i,1) = ...
                ncotp{'Primary_wave_mean_period',...
                 '_surface'}(timeindex,latindex,lonindex);  ...
                    %Wave period
            AIS.NR{j}.waved(i,1) = AIS.NR{j}.data(i,7) - ...
                ncodp{'Primary',...
                 '_wave_direction_surface'}...
                 (timeindex,latindex,lonindex) * pi / 180;  ...
                    %Relative wave direction
            AIS.NR{j}.waved(i,1) = ...
                wrapTo2Pi(AIS.NR{j}.waved(i,1));  %make wave ...
                directions between 0 and 2*pi

        end

        %Wave Resistance Calculation using STAWAVE-2 Method ...
            - from ISO
        %15016 Guidelines for the assessment of speed and power
        %performance by analysis of speed trial data
```

```
for k = 1:size(AIS.NR{j}.stw)  %Do resistance ...
    calculations for each hour individually
    if AIS.NR{j}.waved(k) ≤ 45 * pi / 180 || ...
        AIS.NR{j}.waved(k) ≥ 315 * pi / 180  %Added ...
        resistance for seas plus/minus 45 degrees ...
        off bow

        wave.stw = AIS.NR{j}.stw(k);  %Speed through ...
            water
        wave.Tm = AIS.NR{j}.Tm(k);     %Mean draft
        wave.Hs = AIS.NR{j}.Hs(k);     %Significant ...
            Wave Height
        wave.waveT = AIS.NR{j}.waveT(k);    %Wave period
        wave.rho_w = AIS.NR{j}.rho_w(k);    %Water ...
            density

        %Froude Number
        wave.Fr = wave.stw ./ sqrt( g * ves.length);

        %Wave Frequency
        wave.∆omega = 0.01;
        wave.omega = [0.01:wave.∆omega:10]'; %range ...
            of omegas to use in calculation

        %Mean Wave Amplitude
        wave.zeta = wave.Hs / 2;

        %Eqn D.16
        wave.omega_bar = ( sqrt(ves.length ./ g) * ...
            (kyy).^(1/3) ) ./ ( 1.17 .* ( wave.Fr .^ ...
            (-0.143)) ) .* wave.omega;

        %Eqn D.17
        wave.a1 = 60.3 * ves.CB ^ 1.34;

        %Eqns D.18 and D.19
        for i = 1:size(wave.omega_bar,1)
            if wave.omega_bar(i) < 1
                wave.b1(i,1) = 11.0;
                wave.d1(i,1) = 14.0;
            else
                wave.b1(i,1) = -8.50;
                wave.d1(i,1) = -566 * (ves.length / ...
                    ves.breadth)^(-2.66);
            end
        end

        %Eqn D.15
        wave.raw = wave.omega_bar.^(wave.b1) .* exp( ...
            wave.b1 ./ wave.d1 .* (1- ...
            (wave.omega_bar .^ wave.d1) ) ) .* ...
            wave.a1 .* (wave.Fr .^ 1.50) .* exp( ...
            -3.50 .* wave.Fr );
```

```
                    %Eqn D.14
                    wave.R_AWM = 4 .* wave.rho_w .* g .* ...
                        (wave.zeta .^ 2 ) .* ves.breadth.^2 ./ ...
                        ves.length .* wave.raw;

                    %Wave Number and Wave Length
                    wave.k = ( wave.omega .^ 2 ) ./ g;  %Wave number
                    wave.lambda = 2 * pi ./ wave.k;  %Wave length

                    %Eqn D.22
                    wave.f1 = 0.692 .* (wave.stw ./ sqrt(wave.Tm ...
                        * g) ).^ 0.769 + 1.81 * ves.CB ^ 6.95;

                    %Eqn D.21
                    wave.alpha1 = ( pi^2 .* ( besseli(1, 1.5 .* ...
                        wave.k .* wave.Tm ) ).^2 ) ./ ( pi^2 .* ...
                        ( besseli(1, 1.5 .* wave.k .* wave.Tm ) ...
                        ).^2 + ( besselk(1, 1.5 .* wave.k .* ...
                        wave.Tm ) ).^2 ) .* wave.f1;

                    %Eqn D.20
                    wave.R_AWR = 1/2 .* wave.rho_w .* g .* ...
                        wave.zeta .^2 .* ves.breadth .* wave.alpha1;

                    %Eqn D.13
                    wave.stawave2 = wave.R_AWM + wave.R_AWR;

                    %Calculating Bretschneider Wave Spectrum
                    wave.Tz = 1.296 / 1.41 .* wave.waveT;  %Zero ...
                        Crossing Period
                    wave.A = wave.Hs.^2 ./ (4*pi) .* (2*pi ./ ...
                        wave.Tz).^4;
                    wave.B = 1/pi .* (2*pi/wave.Tz).^4;
                    wave.Sb = wave.A ./ wave.omega.^5 .* exp( ...
                        -wave.B ./ wave.omega.^4 );  ...
                        %Bretschneider Spectrum

                    %Added Resistance (Eqn D.23)
                    AIS.NR{j}.R.wave(k,1) = 2 * ...
                        trapz(wave.omega,wave.stawave2 .* ...
                        wave.Sb ./ wave.zeta.^2);

                else %if waves are not between 0 and 45 degrees ...
                    off bow

                    AIS.NR{j}.R.wave(k,1) = 0;

                end %end if statement
            end %end calculation


%% Calculate Added Resistance Due to Wind

        disp(horzcat('Performing Wind Resistance Calculations...'))
```

```
        %Create Zero Matrices
        AIS.NR{j}.wins = zeros(length(AIS.NR{j}.stw),1);
        AIS.NR{j}.wind = zeros(length(AIS.NR{j}.stw),1);

        for i = 1:length(AIS.NR{j}.stw)
            date = AIS.NR{j}.avgtime(i);
            currentlat = AIS.NR{j}.avglat(i);
            currentlon = AIS.NR{j}.avglon(i);

            %Convert AIS times into vector to create strings
            datevector = datevec(datestr(date));

            %WIND DATA

            %Determine Closest 6-Hour Period for current time
            if 0 ≤ datevector(4) < 3
                datevector(7) = 0;
            elseif 3 ≤ datevector(4) < 9
                datevector(7) = 6;
            elseif 9 ≤ datevector(4) < 15
                datevector(7) = 12;
            elseif 15 ≤ datevector(4) < 24
                datevector(7) = 18;
            end

            % Find Correct File for Wind Data
            filenamestring = horzcat(hindcast_loc, 'Wind\', ...
               num2str(datevector(1)), '\', sprintf('%02d', ...
               datevector(2)), '\', num2str(datevector(1)), ...
               sprintf('%02d',datevector(2)), ...
               sprintf('%02d', datevector(3)), ...
               sprintf('%02d', datevector(7)), ...
               '_6hm-ifremer*.nc');
            filename = dir(filenamestring);
            filename = filename.name;

            %Pull Out Wind Data
            lon = ncread(filename,'longitude');
            lat = ncread(filename,'latitude');
            windu = ncread(filename,'eastward_wind');
            windv = ncread(filename,'northward_wind');

            [¬, latindex] = min(abs(currentlat - lat));
            [¬ ,lonindex] = min(abs(currentlon - lon));

            windu = windu(lonindex,latindex,1,1);  %Eastward ...
               Wind Velocity
            windv = windv(lonindex,latindex,1,1);  ...
               %Northward Wind Velocity

            AIS.NR{j}.wins(i,1) = sqrt(windu^2 + windv^2);  ...
               %Overall Wind Speed
            AIS.NR{j}.wind(i,1) = wrapTo2Pi(pi/2 - ...
```

```
                    atan2(windv,windu));  %Wind Direction from ...
                    True North

            end

            AIS.NR{j}.wind_rel = wrapTo2Pi(AIS.NR{j}.data(i,7) - ...
                AIS.NR{j}.wind);  %Relative Wind Direction

            % % % Calc the WIND FORCE

            %Air Density
            AIS.NR{j}.rho_a = 1.292 * 273 ./ (273 + ...
                AIS.NR{j}.data(:,5));

            % find the cx-values that correspond to each wind ...
                direction (by
            % linear interpolation)
            AIS.NR{j}.cx = interp1(CXdata.angle, CXdata.coef, ...
                AIS.NR{j}.wind_rel(:));   %AIS Wind Angles are ...
                Already in Radians

            %Added Air Resistance
            AIS.NR{j}.R.air = 0.5 * AIS.NR{j}.rho_a .* ...
                (AIS.NR{j}.wins(:).^2) .* CXdata.A_F .* ...
                AIS.NR{j}.cx;




    %% Calculate PE, PD, bare hull resistance, t, w, eta_hull, ...
        eta_RR, eta_0 for each speed

        %Ideal Effective Power for each AIS entry
        AIS.NR{j}.PE_ideal = PEfitresult(AIS.NR{j}.stw);

        %Ideal Delivered Power for each AIS entry
        AIS.NR{j}.PD_ideal = PDfitresult(AIS.NR{j}.stw);

        %Ideal Resistance for each AIS entry
        AIS.NR{j}.R.ideal = Rfitresult(AIS.NR{j}.stw);

        %Thrust Deduction for each AIS entry
        AIS.NR{j}.t = interp1(SP.V,SP.t,AIS.NR{j}.stw);

        %Wake Fraction for each AIS Entry
        AIS.NR{j}.w = interp1(SP.V,SP.w,AIS.NR{j}.stw);

        %Hull Efficiency for each AIS Entry
        AIS.NR{j}.eta_hull = ...
            interp1(SP.V_polyfit,SP.eta_hull_polyfit,AIS.NR{j}.stw);

        %Relative Rotative Efficiency for each AIS Entry
        AIS.NR{j}.eta_RR = ...
            interp1(SP.V_polyfit,SP.eta_RR_polyfit,AIS.NR{j}.stw);
```

```

        %Propeller Open Water Efficiency for each AIS Entry
        AIS.NR{j}.eta_0 = AIS.NR{j}.PE_ideal ./ ( ...
           AIS.NR{j}.PD_ideal .* AIS.NR{j}.eta_hull .* ...
           AIS.NR{j}.eta_RR );

%% Water Properties Correction

        disp(horzcat('Performing Water Properties Resistance ...
           Calculations...'))

            %Ref. values at 15 deg.
            rho.s0 = 1026; %density, kg/m3
            nu.w0 = 1.1892e-06;  %kinematic viscosity
            AIS.NR{j}.Re_0 = AIS.NR{j}.stw .* ves.length ./ ...
               nu.w0;  %Reynolds number at reference conditions
            AIS.NR{j}.CF_0 = 0.075 ./ (log10(AIS.NR{j}.Re_0) - ...
               2).^2;  %Hull frictional coefficient at ...
               reference conditions

            %values at current water temperature
            AIS.NR{j}.Re = AIS.NR{j}.stw .* ves.length ./ ...
               AIS.NR{j}.nu;  %Reynolds number
            AIS.NR{j}.CF = 0.075 ./ (log10(AIS.NR{j}.Re) - ...
               2).^2;  %Frictional coefficient
            AIS.NR{j}.R_F = 0.5 * PE.S .* AIS.NR{j}.rho_w .* ...
               AIS.NR{j}.stw.^2 .* AIS.NR{j}.CF;  %Frictional ...
               Resistance

        %Correction due to water properties
            AIS.NR{j}.R.water = - (AIS.NR{j}.R.ideal .* (1 - ...
               AIS.NR{j}.rho_w / rho.s0) - AIS.NR{j}.R_F .* (1 ...
               - AIS.NR{j}.CF_0 ./ AIS.NR{j}.CF)) ;



 %% Correction due to draft


        disp(horzcat('Performing Draft Calculations...'))

            AIS.NR{j}.Tm = AIS.NR{j}.data(1:end,6);  %Mean Draft

            %difference in draft
            AIS.NR{j}.Δ_T = PE.Tm - AIS.NR{j}.Tm;

            %displacement in ref condition [kg]
            AIS.NR{j}.Displ_ref = PE.nabla * AIS.NR{j}.rho_w;

            %Actual displacement [kg]
            AIS.NR{j}.Displ_act = AIS.NR{j}.Δ_T .* PE.TPM .* ...
               1000 + AIS.NR{j}.Displ_ref;

            %Resistance due to difference in draft
```

```
            AIS.NR{j}.R.draft = 0.65 * AIS.NR{j}.R.ideal .* ...
                (AIS.NR{j}.Displ_ref ./ AIS.NR{j}.Displ_act - 1) ...
                 ;



%% Corrected Resistance

        %Total Delivered [Power * Distance] (Watt-NM)
        AIS.NR{j}.PD = ( NoonRpt.filtered(j,10) .* ...
            NoonRpt.filtered(j,14) + NoonRpt.filtered(j,11) .* ...
            NoonRpt.filtered(j,15) + NoonRpt.filtered(j,12) .* ...
            NoonRpt.filtered(j,16) ) / ISO_LCV_HFO * eta_trans / ...
            me_SFOC * 1000 * 1000 / sum(AIS.NR{j}.dur) * ...
            sum(AIS.NR{j}.dist); %Total Watt-hrs delivered by ...
            ship during noon report duration
        AIS.NR{j}.PD1 = ( NoonRpt.filtered(j,10) .* ...
            NoonRpt.filtered(j,14) + NoonRpt.filtered(j,11) .* ...
            NoonRpt.filtered(j,15) + NoonRpt.filtered(j,12) .* ...
            NoonRpt.filtered(j,16) ) / ISO_LCV_HFO * eta_trans / ...
            me_SFOC * 1000 * 1000 * 60 * 60 ;
        %Total Effective [Power * Distance] (Watt-NM)
        AIS.NR{j}.PE = AIS.NR{j}.PD * sum(AIS.NR{j}.eta_hull .* ...
            AIS.NR{j}.eta_RR .* AIS.NR{j}.eta_0 .* ...
            AIS.NR{j}.dist) / sum(AIS.NR{j}.dist);
        AIS.NR{j}.PE1 = AIS.NR{j}.PD1 * sum(AIS.NR{j}.eta_hull ...
            .* AIS.NR{j}.eta_RR .* AIS.NR{j}.eta_0 .* ...
            AIS.NR{j}.dist) / sum(AIS.NR{j}.dist);
        %Total [Resistance * Distance] (Newton-NM)
        AIS.NR{j}.R.total = AIS.NR{j}.PE / ( sum(AIS.NR{j}.stw ...
            .* AIS.NR{j}.dist) / sum(AIS.NR{j}.dist) );
        AIS.NR{j}.R.total1 = AIS.NR{j}.PE1;
        %Total Mean Resistance (Newton) Corrected for Wind, ...
            Waves, Draft,
        %Water
        AIS.NR{j}.R.hull = ( AIS.NR{j}.R.total - sum( ...
            AIS.NR{j}.R.wave .* AIS.NR{j}.dist ) - sum( ...
            AIS.NR{j}.R.air .* AIS.NR{j}.dist ) - sum( ...
            AIS.NR{j}.R.water .* AIS.NR{j}.dist ) - sum( ...
            AIS.NR{j}.R.draft .* AIS.NR{j}.dist ) ) / ...
            sum(AIS.NR{j}.dist);
        AIS.NR{j}.R.hull1 = ( AIS.NR{j}.R.total1 - sum( ...
            AIS.NR{j}.R.wave .* AIS.NR{j}.dist ) - sum( ...
            AIS.NR{j}.R.air .* AIS.NR{j}.dist ) - sum( ...
            AIS.NR{j}.R.water .* AIS.NR{j}.dist ) - sum( ...
            AIS.NR{j}.R.draft .* AIS.NR{j}.dist ) ) / ...
            sum(AIS.NR{j}.dist);
        % Solving Normalized Fuel Use Per Day at Experienced Speeds
        % (ton/day)
        AIS.NR{j}.Fuel_Norm = AIS.NR{j}.R.hull1 * ( ...
            sum(AIS.NR{j}.stw .* AIS.NR{j}.dist) / ...
            sum(AIS.NR{j}.dist) ) ...
             / eta_trans / (sum(AIS.NR{j}.eta_hull .* ...
                AIS.NR{j}.eta_RR .* AIS.NR{j}.eta_0 .* ...
```

```
                AIS.NR{j}.dist) / sum(AIS.NR{j}.dist))...
            * me_SFOC / 1000 / 1000 * 24;


%% End Calculations

        end %end if statement for NRindices
    end %end number of noon reports

%% % %Create Matrix of Calculated and Measured Resistance Values

    for j = 1:NRcount
        if ismember(j,NRindices)  %Only Perform Calcs for ... NRindices determined above
            R.measured(j,1) = ( sum(AIS.NR{j}.stw .* ... AIS.NR{j}.dur) / sum(AIS.NR{j}.dur) );  ... %Weighted Average of STW
            R.measured(j,2) = AIS.NR{j}.R.hull;  %Hull Resistance
            R.measured(j,3) = AIS.NR{j}.Fuel_Norm;  %Normalized ... Fuel Consumption

            %Measured Fuel Consumption - not normalized
            if isnan(R.measured(j,2))
                R.measured(j,4) = NaN;  %If calculated ... resistance is Nan, set fuel consumption to Nan
            else
                R.measured(j,4) = ( NoonRpt.filtered(j,10) .* ...
                    NoonRpt.filtered(j,14) + ...
                    NoonRpt.filtered(j,11) .* ...
                    NoonRpt.filtered(j,15) + ...
                    NoonRpt.filtered(j,12) .* ...
                    NoonRpt.filtered(j,16) ) / ISO_LCV_HFO / ...
                    NoonRpt.filtered(j,3) * 24;  %Measured fuel ... consumption, normalized for standard fuel ... (ton/day)
            end
        end
    end
    %delete zero rows in matrix
    R.measured( ¬any(R.measured,2), : ) = [];  %rows

%% % %AIS Output Array

        for j = 1:NRcount
            if ismember(j,NRindices)  %Only Perform Calcs for ... NRindices determined above
                AIS.outputarray1(j,1) = j;  %NR Number
                AIS.outputarray1(j,2) = sum( AIS.NR{j}.dur );  ... %Duration
                AIS.outputarray1(j,3) = sum( AIS.NR{j}.dur .* ... AIS.NR{j}.stw / knots );  %Distance Logged
                AIS.outputarray1(j,4) = sum(AIS.NR{j}.dist1);  ... %Distance Observed
                AIS.outputarray1(j,5) = ( sum(AIS.NR{j}.stw .* ...
```

```
                    AIS.NR{j}.dur) / sum(AIS.NR{j}.dur) ) ;  ...
                    %Weighted Average STW
                AIS.outputarray1(j,6) = AIS.NR{j}.Fuel_Norm; ...
                    %Normalized Fuel For STW
                AIS.outputarray1(j,7) = AIS.NR{j}.R.hull/1000; ...
                    %Normalized Hull Resistance for STW
            end
        end

        %delete zero rows
        AIS.outputarray1( ¬any(AIS.outputarray1,2), : ) = [];

        %Output Table 1
        AIS.table1 = array2table(AIS.outputarray1, ...
            'VariableNames', {'NR', 'Length', 'Logged', ...
            'Observed', 'STW', 'NormFuel', 'NormResistanceKN'});

        disp(' ')
        disp(AIS.table1)

        %determine if Hs values are NaN due to missing data
        i = 0;
        for j = 1:NRcount
            if ismember(j,NRindices)  %Only Perform Calcs for ...
                NRindices determined above
                i = i + 1;
                if any(isnan(AIS.NR{j}.Hs))
                    AIS.outputarray2(i,1) = {'**'};  %Mark ...
                        output with **s if wave data was missing
                else
                    AIS.outputarray2(i,1) = {'  '};
                end
            end
        end


        %% Output LaTex File

        %create matrix with used NR numbers
        NRused = NRindices;
        NRused( ¬any(NRused,2), : ) = [];  %rows

        %Change Directory to LaTex folder
        cd(horzcat(working_dir,'LaTex\filt\'));

        %create text file with output
        voyage_name_corr = strrep(voyage_name, '/','_');  ...
            %replace slashes with underscores in directory name
        voyage_name_corr = strrep(voyage_name_corr, ' ','');  ...
            %replace blanks with underscores in directory name
        voyage_name_corr = strrep(voyage_name_corr, '.','');  ...
            %replace periods with underscores in directory name
        fileID = fopen(horzcat(Vessel,'_',voyage_name_corr, ...
            '.tex'),'w');  %create file
```

```

        %write to file
        fprintf(fileID,'%40s\r\n\', ...
           horzcat('\subsection*{','Vessel: ', Vessel, ';  ...
           Voyage Name: ',voyage_name,'}'));
        if strcmp(results1{1}(1:2),'MR')==1
            fprintf(fileID,'%25s\r\n\','\textbf{Vessel Type: MR} ...
               \\');
        elseif strcmp(results1{1}(1:2),'VL')==1
            fprintf(fileID,'%25s\r\n\','\textbf{Vessel Type: ...
               VLCC} \\');
        end
        fprintf(fileID,'%3s\r\n\','\\');
        fprintf(fileID,'%20s\r\n\','\textbf{Filters:} \\');
        fprintf(fileID,'%27s\r\n\',horzcat('\-\hspace{1cm}Draft ...
           Range: $\pm$',num2str(Draft_Range),' meters \\'));
        fprintf(fileID,'%35s\r\n\',horzcat('\-\hspace{1cm}Speed ...
           Standard Deviation Maximum: ...
           ',num2str(Speed_STD_max),' m/s \\'));
        fprintf(fileID,'%35s\r\n\',horzcat('\-\hspace{1cm}Heading ...
           Standard Deviation Maximum: ...
           ',num2str(Heading_STD_max),' rad \\'));
        fprintf(fileID,'%3s\r\n\','\\');

        %Noon Report Table
        fprintf(fileID,'%20s\r\n\', '\textbf{Noon Report Data:} ');
        fprintf(fileID,'%30s\r\n\', ...
           '\renewcommand{\arraystretch}{1.0}');
        fprintf(fileID,'%15s\r\n\', '\begin{table}[H]');
        fprintf(fileID,'%6s\r\n\','    \small');
        fprintf(fileID,'%10s\r\n\','    \centering');
        fprintf(fileID,'%25s\r\n\','    ...
           \resizebox{\columnwidth}{!}{');
        fprintf(fileID,'%30s\r\n\','    ...
           \begin{tabular}{|c|C{2.2cm}|C{2.2cm}',...
            '|c|C{2.4cm}|C{2.4cm}|C{2.4cm}|} \hline');   %CHECK ...
               COLUMNS
        fprintf(fileID,'%86s\r\n\','    NR\# & NR Start & NR End ...
           & Draft (m) & HFO (ton) LCV (MJ/kg) & MDO (ton) LCV ...
           (MJ/kg) & MGO (ton) LCV (MJ/kg) \\ \hline');
        for i = 1:size(NRused,1)
            fprintf(fileID,'%50s %6.2f %3s %6.2f %8s %6.2f %3s ...
               %6.2f %8s %6.2f %3s %6.2f %8s %6.2f ...
               %8s\r\n\',horzcat('    ',num2str(NRused(i)),' & ...
               ',datestr(NoonRpt.dates2(i,1)),' & ...
               ',datestr(NoonRpt.dates2(i,2)),' & ...
               '),NoonRpt.outputarray1(i,3),' & ...
               ',NoonRpt.outputarray1(i,4),' \newline ...
               ',NoonRpt.outputarray1(i,7),' & ...
               ',NoonRpt.outputarray1(i,5),' \newline ...
               ',NoonRpt.outputarray1(i,8),' & ...
               ',NoonRpt.outputarray1(i,6),' \newline ...
               ',NoonRpt.outputarray1(i,9),'\\ \hline');
        end
```

```
        fprintf(fileID,'%16s\r\n\',' 	\end{tabular}}');
        fprintf(fileID,'%20s\r\n\',horzcat('    ...
            \label{tab:',Vessel,'_',voyage_name_corr,'_NR}'));
        fprintf(fileID,'%10s\r\n\','\end{table}');
        %AIS Data Table
        fprintf(fileID,'%20s\r\n\','\textbf{AIS Calculated ...
            Data:} ');
        fprintf(fileID,'%30s\r\n\', ...
            '\renewcommand{\arraystretch}{1.0}');
        fprintf(fileID,'%15s\r\n\','\begin{table}[H]');
        fprintf(fileID,'%6s\r\n\','    \small');
        fprintf(fileID,'%10s\r\n\','    \centering');
        fprintf(fileID,'%25s\r\n\','    ...
            \resizebox{\columnwidth}{!}{');
        fprintf(fileID,'%30s\r\n\','    ...
            \begin{tabular}{|c|C{1.3cm}|C{1.6cm}|',...
            'C{1.5cm}|C{1.5cm}|C{1.5cm}|C{1.7cm}|C{1.4cm}|} ...
                \hline');   %CHECK COLUMNS
        fprintf(fileID,'%86s\r\n\','    NR\# & Length (hr) & ...
            Observed Distance (NM) & Logged Distance (NM) & ...
            Speed Through Water (knots) & Norm. Resistance (kN) ...
            & Norm. Fuel Cons. (ton/day) & Missing Wave Info \\ ...
            \hline');
        for i = 1:size(NRused,1)
            fprintf(fileID,'%4s %2.0f %3s %2.0f %3s %4.0f %3s ...
                %4.0f %3s %6.2f %3s %6.1f %3s %6.2f %3s %3s ...
                %8s\r\n\','    ',AIS.outputarray1(i,1),' & ...
                ',AIS.outputarray1(i,2),' & ...
                ',AIS.outputarray1(i,4),' & ...
                ',AIS.outputarray1(i,3),' & ...
                ',AIS.outputarray1(i,5)/knots,' & ...
                ',AIS.outputarray1(i,7),' & ...
                ',AIS.outputarray1(i,6),' & ...
                ',string(AIS.outputarray2(i)),'\\ \hline');
        end
        fprintf(fileID,'%16s\r\n\','    \end{tabular}}');
        fprintf(fileID,'%20s\r\n\',horzcat('    ...
            \label{tab:',Vessel,'_',voyage_name_corr,'_AIS}'));
        fprintf(fileID,'%10s\r\n\','\end{table}');
        fprintf(fileID,'%20s\r\n\','\textbf{Filtered Data:} \\');
        if size(NoonRpt.draftfilt,1) > 0
            for i = 1:size(NoonRpt.draftfilt,1)
                fprintf(fileID,'%40s\r\n\', ...
                    horzcat('\-\hspace{1cm}Noon Report ...
                    ',num2str(NoonRpt.draftfilt(i)),' filtered ...
                    out due to draft.  \\'));
            end
        end
        if size(NoonRpt.draftfilt,1) > 0
            for i = 1:size(NoonRpt.fuelfilt,1)
                fprintf(fileID,'%40s\r\n\', ...
                    horzcat('\-\hspace{1cm}Noon Report ...
                    ',num2str(NoonRpt.fuelfilt(i)),' filtered ...
                    out due to fuel use.  \\'));
```

```
            end
        end
        if remNR ≠ 0
            for i = 1:size(remNR,2)
                fprintf(fileID,'%35s\r\n\', ...
                    horzcat('\-\hspace{1cm}Noon Report ...
                    ',num2str(remNR(i)),' filtered out manually. ...
                     \\'));
            end
        end
        if size(AIS.accelfilt,1) > 0
            for i = 1:size(AIS.accelfilt,1)
                fprintf(fileID,'%55s\r\n\', ...
                    horzcat('\-\hspace{1cm}Noon Report ...
                    ',num2str(AIS.accelfilt(i)),' filtered out ...
                    due to acceleration.  \\'));
            end
        end
        if size(AIS.maneuvfilt,1) > 0
            for i = 1:size(AIS.maneuvfilt,1)
                fprintf(fileID,'%55s\r\n\', ...
                    horzcat('\-\hspace{1cm}Noon Report ...
                    ',num2str(AIS.maneuvfilt(i)),' filtered out ...
                    due to maneuvering.  \\'));
            end
        end
        if size(AIS.durfilt,1) > 0
            for i = 1:size(AIS.durfilt,1)
                fprintf(fileID,'%55s\r\n\', ...
                    horzcat('\-\hspace{1cm}Noon Report ...
                    ',num2str(AIS.durfilt(i)),' filtered out due ...
                    to inconsistent AIS/NR lengths.  \\'));
            end
        end
        if size(AIS.datafilt,1) > 0
            for i = 1:size(AIS.datafilt,1)
                fprintf(fileID,'%48s\r\n\', ...
                    horzcat('\-\hspace{1cm}Noon Report ...
                    ',num2str(AIS.datafilt(i)),' filtered out ...
                    due to lack of AIS data.  \\'));
            end
        end
        %Map Figure
        fprintf(fileID,'%3s\r\n\','\\');
        fprintf(fileID,'%20s\r\n\','\textbf{Voyage Map:} ');
        fprintf(fileID,'%10s\r\n\','\begin{figure}[H]');
        fprintf(fileID,'%10s\r\n\','    \centering');
        fprintf(fileID,'%25s\r\n\', horzcat('    ...
            \includegraphics{', Vessel,'_', ...
            voyage_name_corr,'_map.png}'));
        fprintf(fileID,'%20s\r\n\', horzcat('    \label{fig:', ...
            Vessel,'_', voyage_name_corr,'_map}'));
        fprintf(fileID,'%10s\r\n\','\end{figure}');
        %Fuel Figure
```

```
        fprintf(fileID,'%20s\r\n\','\textbf{Fuel Consumption ...
           Plot:} ');
        fprintf(fileID,'%10s\r\n\','\begin{figure}[H]');
        fprintf(fileID,'%10s\r\n\','    \centering');
        fprintf(fileID,'%40s\r\n\', horzcat('    ...
           \includegraphics[width=0.8\textwidth]{', Vessel,'_', ...
           voyage_name_corr,'_fuel.png}'));
        fprintf(fileID,'%20s\r\n\', horzcat('    \label{fig:', ...
           Vessel,'_', voyage_name_corr,'_fuel}'));
        fprintf(fileID,'%10s\r\n\','\end{figure}');
        fclose(fileID);

    %% % % Plot Map

        %Manual fix for one voyage due to data issue
        if strcmp(Vessel,'866') == 1 && strcmp(voyage_name,'27') ...
           == 1  %Only currently necessary for this specific voyage
            for j = 1:NRcount
                if ismember(j,NRindices)
                    AIS.NR{j}.avglon = ...
                        wrapTo360(AIS.NR{j}.avglon);  %Wrap ...
                        longitude values to 0 - 360
                end
            end
        end

        %Plot Route Map
        for j = 1:NRcount
            if ismember(j,NRindices)  %Only Perform Calcs for ...
               NRindices determined above
                plotdata.mid(j,1) = NoonRpt.filtered(j,4);  ...
                   %Noon report latitude
                plotdata.mid(j,2) = NoonRpt.filtered(j,5);  ...
                   %Noon report longitude
                plotdata.latmin(j) = min(AIS.NR{j}.avglat) - 10; ...
                    %minimum latitude
                plotdata.latmax(j) = max(AIS.NR{j}.avglat) + 10; ...
                    %maximum latitude
                plotdata.lonmin(j) = min(AIS.NR{j}.avglon) - 10; ...
                    %minimum longitude
                plotdata.lonmax(j) = max(AIS.NR{j}.avglon) + 10; ...
                    %maximum longitude

            end
        end

        %delete zero rows
        plotdata.mid( ¬any(plotdata.mid,2), : ) = [];  %rows
        plotdata.latmin( ¬any(plotdata.latmin,2), : ) = [];  %rows
        plotdata.latmax( ¬any(plotdata.latmax,2), : ) = [];  %rows
        plotdata.lonmin( ¬any(plotdata.lonmin,2), : ) = [];  %rows
        plotdata.lonmin( ¬any(plotdata.lonmin,2), : ) = [];  %rows

        %determine map limits
```

```
        latlim = [min(plotdata.latmin),max(plotdata.latmax)];
        lonlim = [min(plotdata.lonmin),max(plotdata.lonmax)];

        %plot
        figure(1)
        hold on
        load coastlines
        p(1) = axesm('mercator','MapLatLimit',latlim, ...
            'MapLonLimit',lonlim);
        axis off;
        framem on;
        gridm on;
        mlabel on;
        plabel on;
        mlabel('south');
        p(2) = geoshow(coastlat,coastlon,'DisplayType','polygon');
        for j = 1:NRcount
            if ismember(j,NRindices)
                p(3) = ...
                    geoshow(AIS.NR{j}.avglat,AIS.NR{j}.avglon, ...
                    'DisplayType', 'point', 'Marker', '.', ...
                    'MarkerEdgeColor', 'b', 'Markersize', 2); ...
                    %ALL Reports;
            end
        end
        if length(NRused) > 1
            p(5) = geoshow(plotdata.mid(2:end,1), ...
                plotdata.mid(2:end,2), 'DisplayType', 'point' ...
                ,'Marker', 'o', 'MarkerEdgeColor', 'r', ...
                'MarkerFaceColor', 'r'); %Filtered Reports
        else
            p(5) = geoshow(plotdata.mid(1,1), plotdata.mid(1,2), ...
                'DisplayType', 'point', 'Marker', 'o', ...
                'MarkerEdgeColor', 'r', 'MarkerFaceColor', 'r'); ...
                %First Used Report
        end
        p(4) = geoshow(plotdata.mid(1,1), plotdata.mid(1,2), ...
            'DisplayType', 'point', 'Marker', 'o', ...
            'MarkerEdgeColor', 'r', 'MarkerFaceColor', 'g'); ...
            %First Used Report
        [h,icons,¬,¬] = legend(p([4 5 3]), 'First Used Noon ...
            Report', 'Used Noon Reports', 'Used AIS Data ...
            Points', 'Location', 'southoutside', 'Orientation', ...
            'horizontal');
        title(horzcat('Vessel: ',Vessel,'  Voyage: ',voyage_name));
        Plegend = get(h,'Position');
        icons(9).MarkerSize = 6;
        set(h,'Position',[Plegend(1) Plegend(2)-0.15 Plegend(3) ...
            Plegend(4)]);

        %save figure
        print(figure(1),horzcat(Vessel,'_', ...
            voyage_name_corr,'_map.png'), '-dpng')

```

```
%% Resistance and Fuel Consumption Plot    s
        R.curveV = [0:0.1:10]';  %velocities for plotting ...
            resistance curve
        R.curve = Rfitresult(R.curveV);  %Ideal Resistance Curve ...
            over Range
        R.curvefuel = PDfitresult(R.curveV)/ eta_trans * me_SFOC ...
            / 1000 / 1000 * 24;  %Ideal Fuel Curve over Range

        %Resistance plot
        if all(isnan(R.measured(:,1))+isnan(R.measured(:,2))) > ...
            0  %If no valid data exists
            %Do nothing.   disp('No Valid Data.  Stopping ...
                Calculations.')
        else
            figure(2)
            hold on
            p(1) = plot(R.curveV/knots(:,1),R.curve(:,1)/1000);
            p(2) = scatter( R.measured(:,1) / knots, ...
                R.measured(:,2) / 1000, 'MarkerEdgeColor','r');
            legend(p([1 2]),'Model Test Resistance ...
                Curve','Measured Resistance ...
                Points','Location','northwest')
            xlabel('Velocity (knots)')
            ylabel('Resistance (kN)')
            title(horzcat('Normalized Hull Resistance -- Vessel: ...
                ',Vessel,'  Voyage: ',voyage_name))
            xlim([0 16])
            ylim([0 round(max(R.measured(:,2)/1000)+500,-3)])
            grid on
        end

        %Fuel plot
        if all(isnan(R.measured(:,1))+isnan(R.measured(:,2))) > ...
            0  %if no valid data exists
            %Do nothing.   disp('No Valid Data.  Stopping ...
                Calculations.')
        else
            figure(3)
            hold on
            p(1) = plot(R.curveV/knots(:,1),R.curvefuel(:,1));
            p(2) = scatter( R.measured(:,1) / knots, ...
                R.measured(:,3), 'MarkerEdgeColor','r');
            p(3) = scatter( R.measured(:,1) / knots, ...
                R.measured(:,4), '+','MarkerEdgeColor','m');
            legend(p([1 3 2]),'Model Test Fuel Cons.','Measured ...
                Fuel Cons.','Normalized Fuel ...
                Cons.','Location','northwest')
            xlabel('Velocity (knots)')
            ylabel('Fuel Consumption (ton/day)')
            title(horzcat('Normalized Fuel Consumption -- ...
                Vessel: ',Vessel,'  Voyage: ',voyage_name))
            xlim([0 16])
            if strcmp(results1{1}(1:2),'MR')==1
                 ylim([0 40])
```

```
            elseif strcmp(results1{1}(1:2),'VL')==1
                ylim([0 100])
            end

            grid on
            %save figure
            print(figure(3),horzcat(Vessel,'_', ...
                voyage_name_corr, '_fuel.png'), '-dpng')
        end


%% Output Resistance Calculations into Database

        %Select Database File for Resistance Data Output
        cd(working_dir);
        dbfile = fullfile(pwd,'ResistanceDatabase_dummy2.db');
        %If file doesn't exist, create.
        if exist(dbfile) == 0
            conn = sqlite(dbfile,'create');
            createResistanceTable = ['create table ...
                ResistanceResults ' ...
                   '(Vessel VARCHAR, voyage_name VARCHAR, ' ...
                   'Velocity NUMERIC, Fuel NUMERIC, Resistance ...
                       NUMERIC, Wave_Data_Missing VARCHAR, ...
                       Report_Start VARCHAR, Report_End VARCHAR)'];
            exec(conn,createResistanceTable);

        %Otherwise, use existing file
        else
             conn = sqlite(dbfile);
        end

        %Delete existing data from same voyage
        sqlquery11 = horzcat('DELETE FROM ResistanceResults ...
            WHERE Vessel = ''',Vessel,''' and voyage_name = ...
            ''',voyage_name,'''');
        exec(conn,sqlquery11);

        %if resistance data = NaN, replace with -1000 (SQLite ...
            has problems
        %with NaN)
        insertTable = [AIS.outputarray1(:,5), ...
            AIS.outputarray1(:,6), AIS.outputarray1(:,7)];
        for i=1:size(insertTable,1)
            for k=1:size(insertTable,2)
                if isnan(insertTable(i,k))
                    insertTable(i,k) = -1000;
                end
            end
        end

        %create table for NRs with missing wave data
        for i = 1:length(AIS.outputarray2)
            if string(AIS.outputarray2(i,1)) == '**'
```

```
                wavedatamiss{i,1} = 'missing';
            else
                wavedatamiss{i,1} = ' ';
            end
        end
        wavedatamiss = char(wavedatamiss);

        %create table for start and end dates
        for i = 1:NRcount
             if ismember(i,NRindices)
                 datetablestart(i,1) = NoonRpt.report_start(i);
                 datetableend(i,1) = NoonRpt.report_end(i);
             end
        end
        datetablestart( ¬any(datetablestart,2), : ) = [];  %rows
        datetableend( ¬any(datetableend,2), : ) = [];  %rows
        datetablestart = datestr(datetablestart(:,1),'dd mmm ...
            yyyy HH:MM:SS');
        datetableend = datestr(datetableend(:,1),'dd mmm yyyy ...
            HH:MM:SS');

        %Insert Data from Calculations
        tablename = 'ResistanceResults';
        colnames = {'Vessel', 'voyage_name', 'Velocity', 'Fuel', ...
            'Resistance', 'Wave_Data_Missing', 'Report_Start', ...
            'Report_End'};
        for i = 1:length(AIS.outputarray1(:,1))
            insert(conn,tablename,colnames,{Vessel, voyage_name, ...
                insertTable(i,1), insertTable(i,2), ...
                insertTable(i,3), wavedatamiss(i,:), ...
                datetablestart(i,:), datetableend(i,:)})
        end

        close(conn);


%% End Program

        disp(' ')
        disp('Done.')
        load splat   %load sound
        sound(y,Fs)  %play sound to indicate end
```

D Model 2 MATLAB Code

The following is the entire MATLAB script for Model 2 developed in this thesis. It was developed in MATLAB R2016b and may not work correctly in other MATLAB versions.

```
%APPLICATION OF AIS DATA IN VESSEL PERFORMANCE ANALYSIS
%MASTER THESIS - MODEL 2
%DEVELOPED BY DANIEL MANNHEIM

close all
clear
clc

%% % % INPUT DATA

    %Vessel Information
    Vessel = '891';  %input vessel number as characters between ...
        apostrophes
    HullClean = ['22-09-2016']; %set hull cleaning dates for ...
        ship in 'DD-MM-YYYY' string format.  Multiple cleanings ...
        should be separated with semi-colons.
    HullCleanStyle = [1]; %Set hull cleaning style for each hull ...
        cleaning.  Write 1 for Hull and Propeller Cleaning, 2 ...
        for Hull Cleaning Only, 3 for Propeller Cleaning Only

    %Filter Limits
    Draft_Range = 2; %Set plus/minus draft from model test ...
        condition for draft filter, in meters
    Speed_STD_max = 0.1; %Set maximum standard deviation of ...
        speed for acceleration filter, in m/s
    Heading_STD_max = 0.1; %Set maximum standard deviation of ...
        heading for maneuvering filter, in rad
    Min_speed = 3; %Set minimum speed to remove outlier data, in m/s

    %Folder Information
    working_dir = 'C:\Users\Dan\Google Drive\Thesis\Matlab\';  ...
        %working directory
    database_filename = 'C:\Users\Dan\Google ...
        Drive\Thesis\Matlab\shipdatabase.db'; %filename of ...
        database file
    hindcast_loc = 'E:\Hindcast\';  %Location of hindcast data ...
        folder

    %Data File
    Use_Exist_Data = 'TRUE';  %Use existing data file instead of ...
        reading all new hindcast data - saves lots of time ...
        (TRUE/FALSE)
    existdatafile = 'saveddata21062017.mat';

% % % CONSTANTS

```

```
    knots = 0.51444; % 1 knot in m/s
    me_SFOC = 0.175; %main engine specific fuel oil consumption, ...
        kg/kWh
    eta_trans = 0.98; %direct transmission efficiency
    g = 9.81; %m/s2 gravitational acceleration constant
    kyy = 0.25; %Radius of gyration estimate

% % % Load NC Toolbox to read wave hindcast data
    cd('C:\Users\Dan\Documents\MATLAB')
    addpath(fullfile(matlabroot,'toolbox','nctoolbox-master',''))
    setup_nctoolbox;

% % % Load Database File

    dbfile = fullfile(database_filename);
    conn = sqlite(dbfile,'readonly');

%% Begin Data Retrieval

%If Use Existing Data

    if strcmp(Use_Exist_Data,'TRUE')

        % Adding File Location
        addpath(genpath(working_dir))  %Location of Files
        load(existdatafile);
        sqlquery1 = horzcat('SELECT distinct start, end, ...
            lat_mean, lon_mean, sog_mean, hdt_mean, spow_mean, ...
            srpm_mean,  (draught_aft+draught_fore)/2, ...
            air_temperature, pitch_mean, pitch_std, roll_mean, ...
            roll_std, voyagename, strq_mean, sthr_mean, cog_min, ...
            cog_max, cog_mean, cog_std, hdt_min, hdt_max, ...
            hdt_std, sog_min, sog_max, sog_std FROM ...
            SeaLoggerData where vessel_id = ',Vessel,' AND ...
            (lat_mean IS NOT NULL or lat_mean <> "")');
        results1 = fetch(conn,sqlquery1);
        I = ¬cellfun('isempty',results1);  %Determine if cells ...
            are empty
        voyname = results1(:,15);  %Save Voyage Name for Each Point

    else

 %If Not using Existing Data:
%% % % Extract AIS Data
    sqlquery1 = horzcat('SELECT distinct start, end, lat_mean, ...
        lon_mean, sog_mean, hdt_mean, spow_mean, srpm_mean,  ...
        (draught_aft+draught_fore)/2, air_temperature, ...
        pitch_mean, pitch_std, roll_mean, roll_std, voyagename, ...
        strq_mean, sthr_mean, cog_min, cog_max, cog_mean, ...
        cog_std, hdt_min, hdt_max, hdt_std, sog_min, sog_max, ...
        sog_std FROM SeaLoggerData where vessel_id = ',Vessel,' ...
        AND (lat_mean IS NOT NULL or lat_mean <> "")');
    results1 = fetch(conn,sqlquery1);

```

```
    sqlquery1a = horzcat('SELECT name FROM Ships where ...
        SL_vessel_id = ',Vessel);
    results1a = string(fetch(conn,sqlquery1a));

    if strcmp(results1{1}(1:2),'MR')==1
        Tmean = 11;  %Draft during model tests
        Tmin = Tmean - Draft_Range;  %Minimum for draft filter
        Tmax = Tmean + Draft_Range;  %Maximum for draft filter
    elseif strcmp(results1{1}(1:2),'VL')==1
        Tmean = 20.5;
        Tmin = Tmean - Draft_Range;  %Minimum for draft filter
        Tmax = Tmean + Draft_Range;  %Maximum for draft filter
    end

    %Data needs to be cleaned up.
    I = ¬cellfun('isempty',results1);  %Determine if cells are empty
    voyname = results1(:,15);  %Save Voyage Name for Each Point

    %If cells are empty, replace with '-1000'
    for i = 1:size(I,1)
        for j = 1:size(I,2)
            if I(i,j) == 1
                results2(i,j) = results1(i,j);
            else
                results2(i,j) = {'-1000'};
            end
        end
        results2(i,15) = {i};  %use row index instead of voyage name
    end
    results2 = cellfun(@num2str,results2,'UniformOutput',0);  ...
        %converts all cells to same type string

    %create data frame
    data.frame(:,1) = ...
        datenum(cell2mat(results2(:,1)),'yyyy-mm-dd HH:MM:SS'); ...
        %Start of period in Matlab format
    data.frame(:,2) = ...
        datenum(cell2mat(results2(:,2)),'yyyy-mm-dd HH:MM:SS'); ...
        %End of period in Matlab format
    data.frame(:,3:27) = cellfun(@str2double,results2(:,3:27)); ...
        %rest of data

    %Delete rows missing data
    for i = 1:size(data.frame,1)
        if any(data.frame(i,:) == -1000)
            data.frame(i,:) = 0;
        end
    end
    data.frame( ¬any(data.frame,2), : ) = []; %delete blank rows

    %sort data by start time
    data.frame = sortrows(data.frame,1);

    %filter out if draught is out of range
```

```
    for i = 1:size(data.frame,1)
        if data.frame(i,9) < Tmin || data.frame(i,9) > Tmax
            data.frame(i,:) = 0;
        end
    end
    data.frame( ¬any(data.frame,2), : ) = [];  %delete blank rows

    %filter out if speed is out of range - gets rid of outlier data
    for i = 1:size(data.frame,1)
        if data.frame(i,5) < Min_speed
            data.frame(i,:) = 0;
        end
    end
    data.frame( ¬any(data.frame,2), : ) = [];  %delete blank rows

    %filter out if speed std deviation is too large - indicates
    %acceleration
    for i = 1:size(data.frame,1)
        if data.frame(i,27) > Speed_STD_max
            data.frame(i,:) = 0;
        end
    end
    data.frame( ¬any(data.frame,2), : ) = [];  %delete blank rows

    %filter out if heading std deviation is too large - indicates
    %maneuvering
    for i = 1:size(data.frame,1)
        if data.frame(i,24) > Heading_STD_max
            data.frame(i,:) = 0;
        end
    end
    data.frame( ¬any(data.frame,2), : ) = [];  %delete blank rows

    %Separate Data into individual variables for ease
    data.start = data.frame(:,1); %Start Time
    data.end = data.frame(:,2); %End Time
    data.lat = data.frame(:,3);  %Latitude
    data.lon = data.frame(:,4);  %Longitude
    data.sog = data.frame(:,5);  %Speed Over Ground
    data.hdt_mean = data.frame(:,6);  %Heading
    data.spow = data.frame(:,7);  %Shaft Power
    data.srpm = data.frame(:,8);  %Shaft RPM
    data.Tm = data.frame(:,9);  %Mean Draft
    data.airt_nr = data.frame(:,10);  %Air Temperature from NR
    data.pitch_mean = data.frame(:,11);  %Pitch, Mean
    data.pitch_std = data.frame(:,12);  %Pitch, Standard Deviation
    data.roll_mean = data.frame(:,13);  %Roll, Mean
    data.roll_std = data.frame(:,14);  %Roll, Standard Deviation
    data.voyageindex = data.frame(:,15);  %Voyage Index
    data.strq = data.frame(:,16); %Shaft Torque
    data.sthr = data.frame(:,17); %Shaft Thrust
    data.cog_min = data.frame(:,18);  %Minimum Course Over ...
       Ground Angle
    data.cog_max = data.frame(:,19);  %Maximum Course Over ...
```

```
        Ground Angle
    data.cog_mean = data.frame(:,20);  %Mean Course Over Ground ...
        Angle
    data.cog_std = data.frame(:,21);  %Standard Dev. Course Over ...
        Ground Angle
    data.hdt_min = data.frame(:,22);  %Minimum Heading Angle
    data.hdt_max = data.frame(:,23);  %Maximum Heading Angle
    data.hdt_std = data.frame(:,24);  %Standard Dev. Heading Angle
    data.sog_min = data.frame(:,25);  %Minimum Speed Over Ground
    data.sog_max = data.frame(:,26);  %Maximum Speed Over Ground
    data.sog_std = data.frame(:,27);  %Standard Dev. of Speed of ...
        Ground



%% Progress Counter
    completedindices = size(data.frame,1)/100;
    for i = 1:100
        completedmatrix(i,1) = round(i*completedindices);
    end

%% Create Zero Matrices for speed
    data.curs = zeros(size(data.frame,1),1);  %Current Speed
    data.curd = zeros(size(data.frame,1),1);  %Current Direction
    data.temp = zeros(size(data.frame,1),1);  %Water Temperature
    data.salin.PSU = zeros(size(data.frame,1),1);  %Water Salinity
    data.Hs = zeros(size(data.frame,1),1); %Significant Wave Height
    data.waveT = zeros(size(data.frame,1),1);  %Wave Period
    data.waved = zeros(size(data.frame,1),1);  %Wave Direction
    data.wins = zeros(size(data.frame,1),1);  %Wind Speed
    data.wind = zeros(size(data.frame,1),1);  %Wind Direction

%% Retrieve Current Speed Data for Each Period

        % Adding File Location
        addpath(genpath(hindcast_loc))  %Location of Files

        %Find Current Data for each location/time
        disp('Retrieving Data...')

        for i = 1:size(data.frame,1)
            date = data.start(i); %start time of AIS period
            currentlat = data.lat(i);  %latitude of AIS period
            currentlon = wrapTo360(data.lon(i));  %longitude of ...
                AIS Period

            %Convert AIS times into vector to create strings
            datevector = datevec(datestr(date));

            %CURRENTS

                % Find Correct File for Current Data
                filenamestring = horzcat(hindcast_loc, 'CTS\', ...
                    num2str(datevector(1)), '\', sprintf('%02d', ...
```

```
                datevector(2)), '\', ...
                'metoffice_glosea_orca025_GL4_RFVL_*dm', ...
                num2str(datevector(1)), sprintf('%02d', ...
                datevector(2)), sprintf('%02d', ...
                datevector(3)), '.nc');
            filename = dir(filenamestring);
            filename = filename.name;

            %Pull Out Current Data
            lon = ncread(filename,'lon');
            lat = ncread(filename,'lat');
            currentu = ncread(filename,'vozocrtx');  ...
                %Eastward Sea Water Velocity
            currentv = ncread(filename,'vomecrty'); ...
                %Northward Sea Water Velocity

            [¬, latindex] = min(abs(currentlat - lat));
            [¬ ,lonindex] = min(abs(currentlon - lon));

            currentu = currentu(lonindex,latindex,1,1);
            currentv = currentv(lonindex,latindex,1,1);

            data.curs(i,1) = sqrt(currentu^2 + currentv^2);  ...
                %Current speed
            data.curd(i,1) = wrapTo2Pi(pi/2 - ...
                atan2(currentv,currentu));  %%Current ...
                direction. atan2 has 0 at east direction, so ...
                have to correct to be in same orientation as ...
                headings


        % WATER PROPERTIES

            % % % TEMPERATURE

            % Find Correct File for Temperature Data
            filenamestring = horzcat(hindcast_loc, 'CTS\', ...
                num2str(datevector(1)), '\', sprintf('%02d', ...
                datevector(2)), '\', ...
                'metoffice_glosea_orca025_GL4_TEMP_*dm', ...
                num2str(datevector(1)), sprintf('%02d', ...
                datevector(2)), sprintf('%02d', ...
                datevector(3)), '.nc');
            filename = dir(filenamestring);
            filename = filename.name;

            %Pull Out Temperature Data
            lon = ncread(filename,'lon');
            lat = ncread(filename,'lat');
            temp = ncread(filename,'votemper') - 273.15;

            [¬, latindex] = min(abs(currentlat - lat));
            [¬ ,lonindex] = min(abs(currentlon - lon));

```

```
        data.temp(i,1) = temp(lonindex,latindex,1,1);  ...
            %Seawater Temperature  in C

        % % % SALINITY

        % Find Correct File for Salinity Data
        filenamestring = horzcat(hindcast_loc, 'CTS\', ...
            num2str(datevector(1)), '\', sprintf('%02d', ...
            datevector(2)), '\', ...
            'metoffice_glosea_orca025_GL4_PSAL_*dm', ...
            num2str(datevector(1)), sprintf('%02d', ...
            datevector(2)), sprintf('%02d', ...
            datevector(3)),'.nc');
        filename = dir(filenamestring);
        filename = filename.name;

        %Pull Out Salinity Data
        lon = ncread(filename,'lon');
        lat = ncread(filename,'lat');
        salin = ncread(filename,'vosaline');

        [¬, latindex] = min(abs(currentlat - lat));
        [¬ ,lonindex] = min(abs(currentlon - lon));

        data.salin.PSU(i,1) = ...
            salin(lonindex,latindex,1,1); %Salinity, ...
            'PSU [g/kg]'

    % WAVES

        %Creating Strings for Reading Wave Data
        gribdp = horzcat(hindcast_loc, 'Waves\', ...
            'multi_1.glo_30m.dp.', ...
            num2str(datevector(1)), sprintf('%02d', ...
            datevector(2)), '.grb2');  %Direction
        gribhs = horzcat(hindcast_loc, 'Waves\', ...
            'multi_1.glo_30m.hs.', ...
            num2str(datevector(1)), sprintf('%02d', ...
            datevector(2)), '.grb2');  %Sig Wave Height
        gribtp = horzcat(hindcast_loc, 'Waves\', ...
            'multi_1.glo_30m.tp.', ...
            num2str(datevector(1)), sprintf('%02d', ...
            datevector(2)), '.grb2');  %Wave Period

        %Reading Wave Data
        ncodp = ncgeodataset(gribdp);  %Wave Direction
        ncohs = ncgeodataset(gribhs);  %Wave Height
        ncotp = ncgeodataset(gribtp);  %Wave Period

        lat=ncodp{'lat'}(:);
        lon=ncodp{'lon'}(:);
        time=ncodp{'time'}(:);

        [¬, latindex] = min(abs(lat - currentlat));
```

```
            [¬, lonindex] = min(abs(lon - currentlon));
            [¬, timeindex] = min(abs(time - ( ...
                (datevector(3)-1)*24+datevector(4) )));

            %Reading Values at position and time of interest
            data.Hs(i,1) = ...
                ncohs{'Significant_height_of_combined_wind',...
                '_waves_and_swell_surface'}(timeindex, ...
                    latindex, lonindex);  %Significant wave ...
                    height (m)
            data.waveT(i,1) = ...
                ncotp{'Primary_wave_mean_period_',...
                'surface'}(timeindex, latindex, lonindex); ...
                    %Wave period
            data.waved(i,1) = ...
                ncodp{'Primary_wave_direction_',...
                'surface'}(timeindex, latindex, lonindex) * ...
                    pi / 180;  %absolute wave direction, ...
                    waves already have 0 as coming from ...
                    north, 90 as coming from east

        %WIND

            %Determine Closest 6-Hour Period for current time
            if 0 ≤ datevector(4) < 3
                datevector(7) = 0;
            elseif 3 ≤ datevector(4) < 9
                datevector(7) = 6;
            elseif 9 ≤ datevector(4) < 15
                datevector(7) = 12;
            elseif 15 ≤ datevector(4) < 24
                datevector(7) = 18;
            end

            % Find Correct File for Wind Data
            filenamestring = horzcat(hindcast_loc, 'Wind\', ...
                num2str(datevector(1)), '\', sprintf('%02d', ...
                datevector(2)), '\', num2str(datevector(1)), ...
                sprintf('%02d', datevector(2)), ...
                sprintf('%02d', datevector(3)), ...
                sprintf('%02d', datevector(7)), ...
                '_6hm-ifremer*.nc');
            filename = dir(filenamestring);
            filename = filename.name;

            %Pull Out Wind Data
            lon = ncread(filename,'longitude');
            lat = ncread(filename,'latitude');
            windu = ncread(filename,'eastward_wind');
            windv = ncread(filename,'northward_wind');

            [¬, latindex] = min(abs(currentlat - lat));
            [¬ ,lonindex] = min(abs(currentlon - lon));

```

```
                    windu = windu(lonindex,latindex,1,1);
                    windv = windv(lonindex,latindex,1,1);

                    data.wins(i,1) = sqrt(windu^2 + windv^2);  %Wind ...
                        speed
                    data.wind(i,1) = wrapTo2Pi(pi/2 - ...
                        atan2(windv,windu));  %Wind Direction -  ...
                        atan2 has 0 at east direction, so have to ...
                        correct to be in same orientation as headings

                % COUNTER
                    if any(i == completedmatrix)
                        completedpercent = ...
                            round(i/size(data.frame,1) * 100);
                        disp(horzcat(num2str(completedpercent),'% ...
                            Complete'))
                    end
            end

            %Save Data File
            save 'saveddataoutput.mat' data;
        end

    %% Extract Resistance, Powering, Open Water, Self Propulsion, ...
        Etc Data from Database

        % % % Effective Power Curve
        sqlquery4 = horzcat('SELECT x,y,(TF+TA)/2,nabla,TPM,S FROM ...
            ships inner join model_test_data on ...
            Ships.model_test_data_id = model_test_data.ID inner join ...
            model_condition on model_test_data.ID = ...
            model_condition.model_test_data_id inner join ...
            Curve_points on model_condition.PE_curve_id = ...
            Curve_points.Curve_id where SL_vessel_id = ',Vessel);
        results4 = fetch(conn,sqlquery4);
        PE.V = cell2mat(results4(:,1));  %Velocities
        PE.P = cell2mat(results4(:,2));  %Effective Power
        PE.Tm = cell2mat(results4(1,3));  %Mean Draft
        PE.nabla = cell2mat(results4(1,4));  %Displacement
        PE.TPM = cell2mat(results4(1,5));  %Tons per meter immersion
        PE.S = cell2mat(results4(1,6));  %Surface Area

        %PE Curve Fit
        [xData, yData] = prepareCurveData( PE.V, PE.P );
        % Set up fittype and options.
        ft = fittype( 'poly3' );
        opts = fitoptions( 'Method', 'LinearLeastSquares' );
        opts.Lower = [0 0 0 0];
        opts.Upper = [Inf 0 0 0];
        % Fit model to data.
        [PEfitresult, gof] = fit( xData, yData, ft, opts );

        %Convert to Resistance
        R.V = PE.V;
```

```
R.R = PE.P ./ R.V;
%For VLCC, R_ref(1) = NaN because V(1) = 0.  Correct for ...
    future calculations:
if isnan(R.R(1)) == 1
   R.R(1) = 0;
end

%Resistance Curve Fit
[xData, yData] = prepareCurveData( R.V, R.R );
% Set up fittype and options.
ft = fittype( 'poly2' );
opts = fitoptions( 'Method', 'LinearLeastSquares' );
opts.Lower = [0 0 0];
opts.Upper = [Inf 0 0];
% Fit model to data.
[Rfitresult, gof] = fit( xData, yData, ft, opts );

% % % Self Propulsion Curves

sqlquery5 = horzcat('SELECT V, t, w, eta_RR, eta_hull from ...
    ships inner join model_test_data on ...
    Ships.model_test_data_id = model_test_data.ID inner join ...
    model_condition on model_test_data.ID = ...
    model_condition.model_test_data_id inner join SP_curves ...
    on model_condition.SP_curve_id = SP_curves.Curve_id ...
    where SL_vessel_id = ',Vessel);
results5 = fetch(conn,sqlquery5);
SP.V = cell2mat(results5(:,1));  %Velocity
SP.t = cell2mat(results5(:,2));  %Thrust deduction
SP.w = cell2mat(results5(:,3));  %Wake fraction
SP.eta_RR = cell2mat(results5(:,4));  %Relative Rotative ...
    Efficiency
SP.eta_hull = cell2mat(results5(:,5));  %Hull Efficiency
SP.V_polyfit = 0:1*knots:18*knots;  %Velocity range for ...
    spline fit
SP.eta_RR_polyfit = spline(SP.V,SP.eta_RR,SP.V_polyfit);  ...
    %Spline fit of relative rotative efficiency
SP.eta_hull_polyfit = spline(SP.V,SP.eta_hull,SP.V_polyfit); ...
     %Spline fit of hull efficiency

% % % Propeller Diameter
sqlquery6 = horzcat('SELECT D from ships inner join ...
    model_test_data on Ships.model_test_data_id = ...
    model_test_data.ID inner join open_water_data on ...
    model_test_data.open_water_data_ID = open_water_data.ID ...
    where SL_vessel_id = ',Vessel);
results6 = fetch(conn,sqlquery6);
D = cell2mat(results6(:,1));  %Propeller Diameter in m

% % % Delivered Power
sqlquery7 = horzcat('SELECT x, y from ships inner join ...
    model_test_data on Ships.model_test_data_id = ...
    model_test_data.ID inner join model_condition on ...
    model_test_data.ID = model_condition.model_test_data_id ...
```

```
        inner join Curve_points on model_condition.PD_curve_id = ...
        Curve_points.Curve_id where SL_vessel_id = ',Vessel);
    results7 = fetch(conn,sqlquery7);
    PD.V = cell2mat(results7(:,1));  %Velocity
    PD.V(end+1) = 0;  %Manually add in zero velocity starting ...
        point for curve fit
    PD.P = cell2mat(results7(:,2));  %Delivered Power
    PD.P(end+1) = 0;  %Manually add in zero power starting point ...
        for curve fit

    %PD Curve Fit
    [xData, yData] = prepareCurveData( PD.V, PD.P );
    % Set up fittype and options.
    ft = fittype( 'poly3' );
    opts = fitoptions( 'Method', 'LinearLeastSquares' );
    opts.Lower = [-Inf -Inf -Inf -Inf];
    opts.Upper = [Inf Inf Inf Inf];
    % Fit model to data.
    [PDfitresult, gof] = fit( xData, yData, ft, opts );

    % % % Front area of the vessel and Wind Coefficients

    sqlquery2 = horzcat('SELECT area_front from ships inner join ...
        model_test_data on Ships.model_test_data_id = ...
        model_test_data.ID inner join model_condition on ...
        model_test_data.ID = model_condition.model_test_data_id ...
        where SL_vessel_id = ',Vessel);
    results2 = fetch(conn,sqlquery2);
    CXdata.A_F = cell2mat(results2(:,1));  %Frontal area of ship

    sqlquery9 = horzcat('SELECT angle, coef from ships inner ...
        join model_test_data on Ships.model_test_data_id = ...
        model_test_data.ID inner join model_condition on ...
        model_test_data.ID = model_condition.model_test_data_id ...
        inner join wind_coef on model_condition.wind_cx_id = ...
        wind_coef.Curve_id where SL_vessel_id = ',Vessel);
    results9 = fetch(conn,sqlquery9);
    CXdata.angle = cell2mat(results9(:,1));  %Angles for Wind ...
        Coefficients
    CXdata.coef = cell2mat(results9(:,2));  %Wind coefficients

    % % % Vessel Particulars
    sqlquery10 = horzcat('SELECT length, breadth, CB from ships ...
        where SL_vessel_id = ',Vessel);
    results10 = fetch(conn,sqlquery10);
    ves.length = cell2mat(results10(:,1)); %Length of ship
    ves.breadth = cell2mat(results10(:,2)); %Beam of ship
    ves.CB = cell2mat(results10(:,3));  %Block coefficient of ship

    % % % Open Water Curves
    sqlquery3 = horzcat('SELECT J, KT, KQ, eta from ships inner ...
        join model_test_data on Ships.model_test_data_id = ...
        model_test_data.ID inner join open_water_data on ...
        model_test_data.open_water_data_id = open_water_data.ID ...
```

```
        inner join OW_Curves on OWcurve_id = OW_Curves.curve_ID ...
        where SL_vessel_id = ',Vessel);
    results3 = fetch(conn,sqlquery3);
    OW.J = cell2mat(results3(:,1));  %Advance ratio
    OW.KT = cell2mat(results3(:,2));  %Thrust coefficient
    OW.KQ = cell2mat(results3(:,3));  %Torque coefficient
    OW.eta0 = cell2mat(results3(:,4));  %Open water efficiency

%% Begin Calculations

    %% Speed Through Water

        %Current Speed at Each Location in Direction of Travel
        data.curs_dir = -data.curs .* cos( data.curd - ...
           data.hdt_mean );

        %Speed Between Locations with Currents
        data.stw = data.sog + data.curs_dir;

      %% Determining Water Properties

        %Convering salinity from PSU to PPM
        data.salin.PPM = data.salin.PSU * 1.004715 * 1000;  ...
           %%Salinity in Parts Per Million, Researchgate ...
           printed website pdf

        % % % Calculate Seawater Density

        % El-Dessouky, Ettouny (2002) A.1
        rho.B = ( (2) .* (data.salin.PPM) ./ 1000 - 150 ) ./ 150;
        rho.G1 = 0.5;
        rho.G2 = rho.B;
        rho.G3 = 2 * rho.B.^2 - 1;
        rho.A1 = 4.032219 .* rho.G1 + 0.115313 .* rho.G2 + ...
           3.26e-4 .* rho.G3;
        rho.A2 = -0.108119 .* rho.G1 + 1.571e-3 .* rho.G2 - ...
           4.233e-4 .* rho.G3;
        rho.A3 = -0.012247 .* rho.G1 + 1.74e-3 .* rho.G2 - 9e-6 ...
           .* rho.G3;
        rho.A4 = 6.92e-4 .* rho.G1 - 8.7e-5 .* rho.G2 - 5.3e-5 ...
           .* rho.G3;
        rho.A = ( (2) .* (data.temp) - 200 )./160;
        rho.F1 = 0.5;
        rho.F2 = rho.A;
        rho.F3 = 2 .* rho.A.^2 - 1;
        rho.F4 = 4 .* rho.A.^3 - 3.*rho.A;
        data.rho_w = 10^3 .* (rho.A1 .* rho.F1 + rho.A2 .* ...
           rho.F2 + rho.A3 .* rho.F3 + rho.A4 .* rho.F4);

        % % % Calculate Seawater Kinematic Viscosity

        % El-Dessouky, Ettouny (2002) A.3
        visc.A = 1.474e-3 + 1.5e-5 .* data.temp - 3.927e-8 .* ...
           data.temp.^2;
```

```
        visc.B = 1.0734e-5 - 8.5e-8 .* data.temp + 2.23e-10 .* ...
            data.temp.^2;
        visc.mu_R = 1 + visc.A .* data.salin.PSU + visc.B .* ...
            data.salin.PSU.^2;
        visc.mu_W = exp( -3.79418 + 604.129 ./ (139.18 + ...
            data.temp ) );
        visc.mu = visc.mu_W .* visc.mu_R .* 10^-3;  %kg/m s
        data.nu = visc.mu ./ data.rho_w;

    %% Calculate Wave Added Resistance


        %Correct direction to be relative to ship heading
        data.waved(:,1) = wrapTo2Pi(data.hdt_mean - data.waved); ...
             %waves already have 0 as true north

        %Wave Resistance Calculation using STAWAVE-2 Method - ...
            from ISO 15016 Guidelines for the assessment of ...
            speed and power performance by analysis of speed ...
            trial data
        for j = 1:size(data.stw)   %Do calculation for each period

            if data.waved(j) ≤ 45 * pi / 180 || data.waved(j) ≥ ...
                315 * pi / 180   %Added resistance for seas ...
                plus/minus 45 degrees off bow

                wave.stw = data.stw(j);  %Speed through water
                wave.Tm = data.Tm(j);    %Mean draft
                wave.Hs = data.Hs(j);    %Significant wave height
                wave.waveT = data.waveT(j);  %Wave period
                wave.rho_w = data.rho_w(j);  %Water density


                %Froude Number
                wave.Fr = wave.stw ./ sqrt( g * ves.length);

                %Wave Frequency
                ∆omega = 0.01;
                wave.omega = [0.01:∆omega:10]'; %range of omegas ...
                    to use in calculation

                %Wave Amplitude
                wave.zeta = wave.Hs / 2;

                %D.16
                wave.omega_bar = ( sqrt(ves.length ./ g) * ...
                    (kyy).^(1/3) ) ./ ( 1.17 .* ( wave.Fr .^ ...
                    (-0.143)) ) .* wave.omega;

                %D.17
                wave.a1 = 60.3 * ves.CB ^ 1.34;

                %D.18 and D.19
                for i = 1:size(wave.omega_bar,1)
```

```
        if wave.omega_bar(i) < 1
            wave.b1(i,1) = 11.0;
            wave.d1(i,1) = 14.0;
        else
            wave.b1(i,1) = -8.50;
            wave.d1(i,1) = -566 * (ves.length / ...
                ves.breadth)^(-2.66);
        end
    end

    %D.15
    wave.raw = wave.omega_bar.^(wave.b1) .* exp( ...
        wave.b1 ./ wave.d1 .* (1- (wave.omega_bar .^ ...
        wave.d1) ) ) .* wave.a1 .* (wave.Fr .^ 1.50) ...
        .* exp( -3.50 .* wave.Fr );

    %D.14
    wave.R_AWM = 4 .* wave.rho_w .* g .* (wave.zeta ...
        .^ 2 ) .* ves.breadth.^2 ./ ves.length .* ...
        wave.raw;

    %Wave Number and Wave Length
    wave.k = ( wave.omega .^ 2 ) ./ g;
    wave.lambda = 2 * pi ./ wave.k;

    %D.22
    wave.f1 = 0.692 .* (wave.stw ./ sqrt(wave.Tm * ...
        g) ).^ 0.769 + 1.81 * ves.CB ^ 6.95;

    %D.21
    wave.alpha1 = ( pi^2 .* ( besseli(1, 1.5 .* ...
        wave.k .* wave.Tm ) ).^2 ) ./ ( pi^2 .* ( ...
        besseli(1, 1.5 .* wave.k .* wave.Tm ) ).^2 + ...
        ( besselk(1, 1.5 .* wave.k .* wave.Tm ) ).^2 ...
        ) .* wave.f1;

    %D.20
    wave.R_AWR = 1/2 .* wave.rho_w .* g .* wave.zeta ...
        .^2 .* ves.breadth .* wave.alpha1;

    %D.13
    wave.stawave2 = wave.R_AWM + wave.R_AWR;

    %Calculating Response Spectrum
    %Zero Crossing Period
    wave.Tz = 1.296 / 1.41 .* wave.waveT;  %Ship ...
        Operations text 4.21

    %Bretschneider Spectrum
    wave.A = wave.Hs.^2 ./ (4*pi) .* (2*pi ./ ...
        wave.Tz).^4; %Ship Operations text 4.20
    wave.B = 1/pi .* (2*pi/wave.Tz).^4;  %Ship ...
        Operations text 4.20
    wave.Sb = wave.A ./ wave.omega.^5 .* exp( ...
```

```
                    -wave.B ./ wave.omega.^4 );  %Ship ...
                    Operations text 4.20

                %Added Resistance (D.23)
                data.R.wave(j,1) = 2 * ...
                    trapz(wave.omega,wave.stawave2 .* wave.Sb ./ ...
                    wave.zeta.^2);

            elseif isnan(data.waved(j))  %If wave data doesn't ...
                exist due to hindcast data set
                data.R.wave(j,1) = NaN;  %Set to Nan
            else %if waves are not between 0 and 45 degrees off bow
                data.R.wave(j,1) = 0;
            end %end if statement
        end %end calculation

    %% Calculate Added Resistance Due to Wind

        data.wind_d = wrapTo2Pi(data.hdt_mean - data.wind );  ...
            %Apparent Wind Angle

        % % % Calc the WIND FORCE
        data.rho_a = 1.292 * 273 ./ (273 + data.airt_nr);  %Air ...
            Density

        % find the cx-values that correspond to each wind direction
        % (by linear interpolation)
        data.cx = ...
            interp1(CXdata.angle,CXdata.coef,data.wind_d(:));   ...
            %AIS Wind Angles are Already in Radians

        %calculate the wind resistance
        data.R.air = 0.5 * data.rho_a .* (data.wins.^2) .* ...
            CXdata.A_F .* data.cx;



  %% Calculate ideal PE, PD, bare hull resistance for each speed

        %Ideal Effective Power for each AIS Entry
        data.PE_ideal = PEfitresult(data.stw);

        %Ideal Delivered Power for each AIS Entry
        data.PD_ideal = PDfitresult(data.stw);

        %Ideal Resistance for each AIS entry
        data.R.ideal = Rfitresult(data.stw);


%% Water Properties Correction

        % ref. values at 15 deg.
        rho.s0 = 1026; %kg/m3
        nu.w0 = 1.1892e-06;  %kinematic viscosity
```

```
        data.Re_0 = data.stw .* ves.length ./ nu.w0;  %Reynolds ...
            number at reference conditions
        data.CF_0 = 0.075 ./ (log10(data.Re_0) - 2).^2;  ...
            %Frictional coefficient at reference conditions

        %values at current water temperature
        data.Re = data.stw .* ves.length ./ data.nu;  %Reynolds ...
            number
        data.CF = 0.075 ./ (log10(data.Re) - 2).^2;  %Frictional ...
            coefficient
        data.R_F = 0.5 * PE.S .* data.rho_w .* data.stw.^2 .* ...
            data.CF;  %Frictional resistance

        %Correction due to water properties
        data.R.water = -(data.R.ideal .* (1 - data.rho_w / ...
            rho.s0) - data.R_F .* (1 - data.CF_0 ./ data.CF)) ;



%% Correction due to draft

        %difference in draft
        data.Δ_T = PE.Tm - data.Tm;

        %displacement in ref condition [kg]
        data.Displ_ref = PE.nabla * data.rho_w;

        %Actual displacement [kg]
        data.Displ_act = data.Δ_T .* PE.TPM .* 1000 + ...
            data.Displ_ref;

        %Resistance correction due to difference in draft
        data.R.draft = 0.65 * data.R.ideal .* (data.Displ_ref ./ ...
            data.Displ_act - 1)  ;


%% Overall Resistance Calculations

    data.Q.meas = data.strq;  %Measured shaft torque
    data.n.meas = data.srpm / 60;  %Measured shaft revolutions ...
        in rpms
    data.PD.meas = 2 * pi * data.Q.meas .* data.n.meas;  ...
        %Measured delivered power
    data.fuel.meas = data.PD.meas * me_SFOC / 1000 / 1000 * 24;  ...
        %Measured fuel consumption per day

    %Ideal Thrust deduction
    data.t = interp1(SP.V,SP.t,data.stw);  %Thrust deduction for ...
        each speed

    %Calculate Thrust and Adjusted Wake Fraction
    data.KQ.meas = data.Q.meas ./ (data.rho_w .* data.n.meas.^2 ...
        .* D^5);
    data.J.meas = interp1(OW.KQ,OW.J,data.KQ.meas);
```

```
    data.KT.meas = interp1(OW.J,OW.KT,data.J.meas);
    data.T.meas = data.KT.meas .* data.rho_w .* data.n.meas.^2 ...
        .* D^4;
    data.w = 1 - data.J.meas .* data.n.meas .* D ./ data.stw;

    %Measured resistance
    data.R.meas = data.T.meas.* (1 - data.t);

    %Corrected Resistance
    data.R.corr = data.R.meas - data.R.wave - data.R.air - ...
        data.R.water - data.R.draft;

    %Relative rotative efficiency
    [xData, yData] = prepareCurveData( SP.V, SP.eta_RR );
    ft = fittype( 'smoothingspline' );
    [fitresult, gof] = fit( xData, yData, ft );
    data.eta_RR = fitresult(data.stw);

    %Ideal wake fraction
    [xData, yData] = prepareCurveData( SP.V, SP.w );
    ft = fittype( 'smoothingspline' );
    [fitresult, gof] = fit( xData, yData, ft );
    data.w2 = fitresult(data.stw);
    %Ideal Hull Efficiency
    data.etah2 = (1 - data.t) ./ (1 - data.w2);
    %Ideal Open Water Efficiency for each speed
    data.eta0 = data.PE_ideal ./ ( data.PD_ideal .* data.etah2 ...
        .* data.eta_RR );

    %Adjusted Hull Efficiency Assuming ideal open water efficiency
    data.etah = (1 - data.t) ./ (1 - data.w);

    %Corrected Delivered Power
    data.PD.corr = data.R.corr .* data.stw ./ (data.eta_RR .* ...
        data.eta0 .* data.etah);

    %Normalized Fuel Consumption (ton/day)
    data.fuel.corr = data.PD.corr * me_SFOC / 1000 / 1000 * 24;

%% Plotting Fuel Curves and Maps

    %Determine Voyage Names for Each Period
    for i = 1:size(data.stw,1)
        data.voyname{i,1} = voyname{data.voyageindex(i)};
    end
    uniquenames = unique(data.voyname);  %Unique voyage names

    %Define group based on voyage names
    for j = 1:size(uniquenames)
       for i = 1:size(data.stw,1)
            if strcmp(data.voyname(i),uniquenames(j)) == 1
                data.groupname(i) = j;
            end
       end
```

```
    end

    %Fuel consumption curve from delivered power model test curve
    data.fuelcurve = PDfitresult(0:0.1:10) * me_SFOC / 1000 / ...
        1000 * 24;

    %Change Directory to LaTex output folder and create corrected
    %filenames
    cd(horzcat(working_dir,'LaTex\Model2Output\'));
    voyage_name_corr = strrep(uniquenames,'/','_');  %replace ...
        slashes with underscores in directory name
    voyage_name_corr = strrep(voyage_name_corr,'.','');  ...
        %replace periods with underscores in directory name
    voyage_name_corr = strrep(voyage_name_corr,' ','');  ...
        %replace blanks with underscores in directory name

    %Plotting fuel consumption plots for all voyage
    for i = 1:size(uniquenames,1)
        figure(i)
        hold on
        scatter(data.stw(data.groupname == ...
            i)/knots,data.fuel.meas(data.groupname == i),'.')
        scatter(data.stw(data.groupname == ...
            i)/knots,data.fuel.corr(data.groupname == i),'.')
        plot((0:0.1:10)/knots,data.fuelcurve,'k')
        legend('Measured Fuel Cons.','Corrected Fuel ...
            Cons.','Model Test Fuel Cons.','Location','Northwest')
        xlabel('Speed Through Water (knots)')
        ylabel('Fuel Consumption (ton/day)')
        xlim([0 16])
        ylim([0 100])
        grid on
        title(horzcat('Normalized Fuel Consumption - Vessel: ...
            ',Vessel,'  Voyage: ',char(uniquenames(i))))
        %save figure
        print(figure(i), horzcat(Vessel, '_', ...
            char(voyage_name_corr(i)), '_fuel.png'), '-dpng')
    end

    %Map
    for i = 1:size(uniquenames,1)
        %determine map points and limits for each voyage
        plotlat = (data.lat(data.groupname == i));
        plotlon = (data.lon(data.groupname == i));
        latlim = [min(plotlat)-10,max(plotlat)+10];
        lonlim = [min(plotlon)-10,max(plotlon)+10];

        %plot
        figure(i+size(uniquenames,1))
        hold on
        load coastlines
        p(1) = axesm('mercator','MapLatLimit', latlim, ...
            'MapLonLimit', lonlim);
        axis off;
```

```
        framem on;
        gridm on;
        mlabel on;
        plabel on;
        mlabel('south');
        p(2) = geoshow(coastlat,coastlon,'DisplayType','polygon');
        p(3) = geoshow(plotlat,plotlon,'DisplayType','point', ...
            'Marker', '.', 'MarkerEdgeColor', 'r'); %AIS points
        p(4) = ...
            geoshow(plotlat(1),plotlon(1),'DisplayType','point', ...
            'Marker', 'o', 'MarkerEdgeColor', 'r', ...
            'MarkerFaceColor', 'g', 'MarkerSize', 5); %First AIS ...
            point
        [h,icons,¬,¬] = legend(p([4 3]),'First AIS Location', ...
            'AIS Locations', 'Location', 'southoutside', ...
            'Orientation', 'horizontal');
        title(horzcat('Voyage Map - Vessel: ',Vessel,'  Voyage: ...
            ',char(uniquenames(i))))
        Plegend = get(h,'Position');
        %save figure
        print(figure(i+size(uniquenames,1)), horzcat(Vessel, ...
            '_', char(voyage_name_corr(i)), '_map.png'), '-dpng')
    end

%% Determine data sets defined by hull cleanings

        HullClean = datenum(HullClean,'dd-mm-yyyy');  %Convert ...
            hull cleaning dates into numbers

        %Define groups for splitting analysis
        if size(HullClean,1) == 0  %if no hull cleanings...
            data.group = ones(size(data.stw,1),1);  %set all ...
                data points to be in same group
        elseif size(HullClean,1) == 1  %if one hull cleaning...
            for i = 1:size(data.stw,1)
                if data.start(i) < HullClean
                    data.group(i,1) = 1;  %split into two groups
                else
                    data.group(i,1) = 2;
                end
            end
        elseif size(HullClean,1) > 1  %if more than one hull ...
            cleaning...
            for i = 1:size(data.stw,1)
                if data.start(i) < HullClean(1)
                    data.group(i,1) = 1;
                elseif data.start(i) ≥ HullClean(1) && ...
                        data.start(i) < HullClean(end)
                    for j = 2:size(HullClean,1)
                        if data.start(i) ≥ HullClean(j-1) && ...
                            data.start(i) < HullClean(j)
                            data.group(i,1) = j;
                        end
                    end
```

```
                elseif data.start(i) ≥ HullClean(end)
                    data.group(i,1) = size(HullClean,1)+1;
                end
            end
        end

%% Fuel Index Over Time

    data.stw = data.stw/knots;  %Convert STW to knots

    %determine date limits
    mindate = datevec(min(data.start)); %first date
    mindate(3) = 1; %round to first day of month
    mindate(4:6) = 0; %set time to be 00:00:00
    maxdate = datevec(max(data.end)); %end date
    maxdate(2) = maxdate(2) + 1; %round to next month
    maxdate(3) = 1; %round to first day of month
    maxdate(4:6) = 0; %set time to be 00:00:00
    nummonths = months(datestr(mindate),datestr(maxdate)); ...
       %number of months between start and end
    for i = 1:nummonths + 1
       xdates(i,1) = datenum(mindate + (i-1) * [0 1 0 0 0 0]);  ...
          %create labels for each month start
    end

    %fuel index figure
    figure(size(uniquenames,1)*2+1)
    title(horzcat('Vessel ',Vessel,' Fuel Index'))
    hold on
    %plot scatter of all points
    p(1) = scatter(data.start,data.fuel.corr./data.stw.^3, '.', ...
       'MarkerEdgeColor', W'b');
    %create fuel index linear fit for all periods
    for i = 1:size(HullClean,1)+1
        if size(data.start(data.group == i),1) > 2
            [xData, yData] = prepareCurveData( ...
               data.start(data.group == i), ...
               data.fuel.corr(data.group == ...
               i)./data.stw(data.group == i).^3 );
            ft = fittype( 'poly1' );
            opts = fitoptions( 'Method', ...
               'LinearLeastSquares','Robust','Off');
            opts.Lower = [-Inf -Inf];
            opts.Upper = [Inf Inf];
            [fit1, gof1] = fit( xData, yData, ft, opts );
            p(2) = plot(data.start(data.group == ...
               i),fit1(data.start(data.group == ...
               i)),'b','Linewidth',2);
        end
    end
    %Plot Hull Cleanings
    for i = 1:size(HullClean,1)
        plot([HullClean(i) HullClean(i)],[0 0.8],'k')
    end
```

```
    %Labels and limits
    xlim([min(xdates) max(xdates)])
    ylim([0 0.1])
    ylabel('Fuel Index')
    ax = gca;
    ax.XTick = xdates;
    xticklabels(datestr(xdates,'dd-mm-yy'))
    if strcmp(results1{1}(1:2),'MR')==1
        ax.YTick = [0 0.005 0.01 0.015 0.02 0.025 0.03];
    elseif strcmp(results1{1}(1:2),'VL')==1
        ax.YTick = [0.00 0.02 0.04 0.06 0.08 0.10];
    end

    xtickangle(35)
    grid on
    legend(p([1 2]),'Measured Fuel Index','Linear ...
       Fit','Location','southoutside','Orientation','Horizontal')
    %Hull cleaning text
    for i = 1:size(HullClean,1)
        if HullCleanStyle(i) == 1
            ht = text(HullClean(i) + 5,0.098,'Hull and Propeller ...
               Cleaning','HorizontalAlignment','right', ...
               'Rotation',90);
        elseif HullCleanStyle(i) == 2
            ht = text(HullClean(i) + 5,0.098,'Hull ...
               Cleaning','HorizontalAlignment','right', ...
               'Rotation',90);
        elseif HullCleanStyle(i) == 3
            ht = text(HullClean(i) + 5,0.098,'Propeller ...
               Cleaning','HorizontalAlignment','right', ...
               'Rotation',90);
        end
    end
    %save figure
    print(figure(size(uniquenames,1)*2+1),horzcat(Vessel, ...
       '_fuelindex.png'), '-dpng')

%% Output LaTex File

    %create file
    fileID = fopen(horzcat(Vessel,'_output.tex'),'w');  %create file
    %write to file
    fprintf(fileID,'%20s\r\n\',horzcat('\subsection*{','Vessel: ...
       ',Vessel,'}'));
    if strcmp(results1{1}(1:2),'MR')==1
        fprintf(fileID,'%25s\r\n\','\textbf{Vessel Type: MR} \\');
    elseif strcmp(results1{1}(1:2),'VL')==1
        fprintf(fileID,'%25s\r\n\','\textbf{Vessel Type: VLCC} \\');
    end
    fprintf(fileID,'%3s\r\n\','\\');
    fprintf(fileID,'%20s\r\n\','\textbf{Filters:} \\');
    fprintf(fileID,'%27s\r\n\',horzcat('\-\hspace{1cm}Draft ...
       Range: $\pm$',num2str(Draft_Range),' meters \\'));
    fprintf(fileID,'%35s\r\n\',horzcat('\-\hspace{1cm}Speed ...
```

```
        Standard Deviation Maximum: ',num2str(Speed_STD_max),' ...
        m/s \\'));
    fprintf(fileID,'%35s\r\n\',horzcat('\-\hspace{1cm}Heading ...
        Standard Deviation Maximum: ',num2str(Heading_STD_max),' ...
        rad \\'));
    fprintf(fileID,'%3s\r\n\','\\');
    %Fuel Index Figure
    fprintf(fileID,'%20s\r\n\','\textbf{Fuel Index:} ');
    fprintf(fileID,'%10s\r\n\','\begin{figure}[H]');
    fprintf(fileID,'%10s\r\n\','    \centering');
    fprintf(fileID,'%40s\r\n\',horzcat('    ...
        \includegraphics[width=0.8\textwidth]{', ...
        Vessel,'_fuelindex.png}'));
    fprintf(fileID,'%10s\r\n\','\end{figure}');
    fprintf(fileID,'%10s\r\n\','\newpage');
    %Individual Voyages
    for i = 1:size(uniquenames,1)
    %Map Figure
        fprintf(fileID,'%20s\r\n\',horzcat('\textbf{Voyage: ...
            ',char(uniquenames(i)),'} '));
        fprintf(fileID,'%10s\r\n\','\begin{figure}[H]');
        fprintf(fileID,'%10s\r\n\','    \centering');
        fprintf(fileID,'%40s\r\n\',horzcat('    ...
            \includegraphics{',Vessel, '_', ...
            char(voyage_name_corr(i)), '_map.png}'));
        fprintf(fileID,'%10s\r\n\','\end{figure}');
        %Fuel Figure
        fprintf(fileID,'%10s\r\n\','\begin{figure}[H]');
        fprintf(fileID,'%10s\r\n\','    \centering');
        fprintf(fileID,'%40s\r\n\',horzcat('    ...
            \includegraphics[width=0.8\textwidth]{', Vessel,'_', ...
            char(voyage_name_corr(i)), '_fuel.png}'));
        fprintf(fileID,'%10s\r\n\','\end{figure}');
        if i < size(uniquenames,1)
            fprintf(fileID,'%10s\r\n\','\newpage');
        end
    end
    fclose(fileID);
```

Application of Automatic Position Information Data in Vessel Performance Analysis

Voyage Report Supplement

Daniel S. Mannheim
Kongens Lyngby, 29 June 2017

Preface

The voyage reports included in this supplement are provided in support of the Master thesis titled "Application of Automatic Position Information Data in Vessel Performance Analysis" submitted in a separate file. The voyage reports are intended to provide backup data for the calculations performed in the thesis.

Kongens Lyngby, 29 June 2017

Daniel S. Mannheim

Contents

1 Model 1 Voyage Reports - Static and Dynamic Filters

This section includes the voyage reports from Model 1 using both the static and dynamic filters. When running these models in MATLAB, the maximum standard deviation of both the speed and heading were set to 0.1.

Results which are marked with "Missing Wave Info" indicates that the hindcast data set used for wave details did not include data for the specific location analyzed. Results which are shown as "NaN" indicates that the hindcast data set used for ocean currents did not include data for the specific location analyzed. In both cases, these data points are not used in the overall performance analysis performed as part of this thesis.

Vessel: 885; Voyage Name: 4025008

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
27	24-Sep-2016 06:00:00	25-Sep-2016 06:00:00	20.62	88.10 40.60	0.00 42.20	0.00 42.20
28	25-Sep-2016 06:00:00	26-Sep-2016 05:00:00	20.62	84.60 40.60	0.00 42.20	0.00 42.20

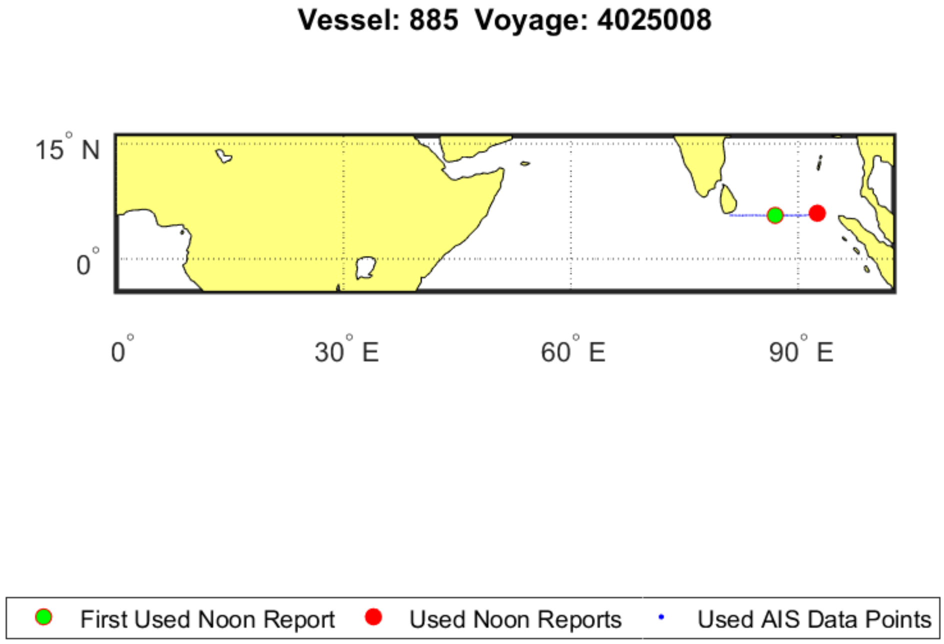
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
27	24	374	348	14.49	2164.0	89.04	
28	23	331	327	14.20	2182.5	87.75	

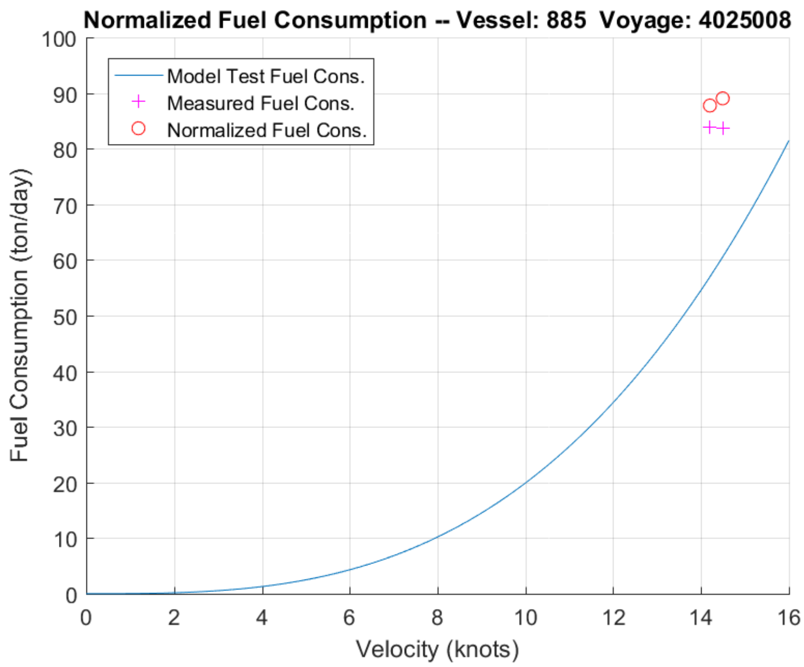
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 24 filtered out due to acceleration.
Noon Report 26 filtered out due to acceleration.
Noon Report 20 filtered out due to maneuvering.
Noon Report 21 filtered out due to maneuvering.
Noon Report 22 filtered out due to maneuvering.
Noon Report 25 filtered out due to maneuvering.
Noon Report 29 filtered out due to maneuvering.
Noon Report 19 filtered out due to inconsistent AIS/NR lengths.
Noon Report 23 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 885; Voyage Name: 4025009

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
19	05-Nov-2016 07:00:00	06-Nov-2016 07:00:00	20.90	73.70 40.60	0.00 42.20	0.00 42.20

AIS Calculated Data:

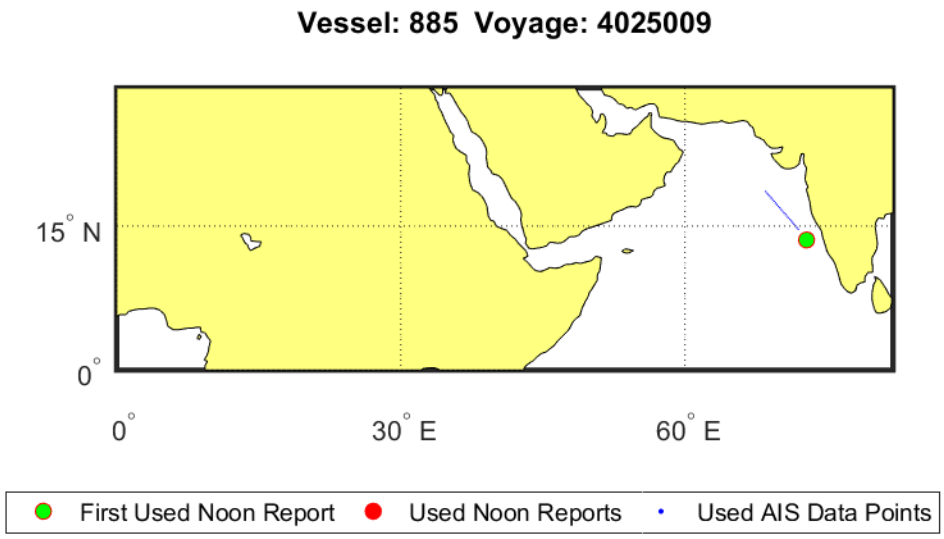
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
19	24	314	312	13.01	1935.8	71.27	

Filtered Data:

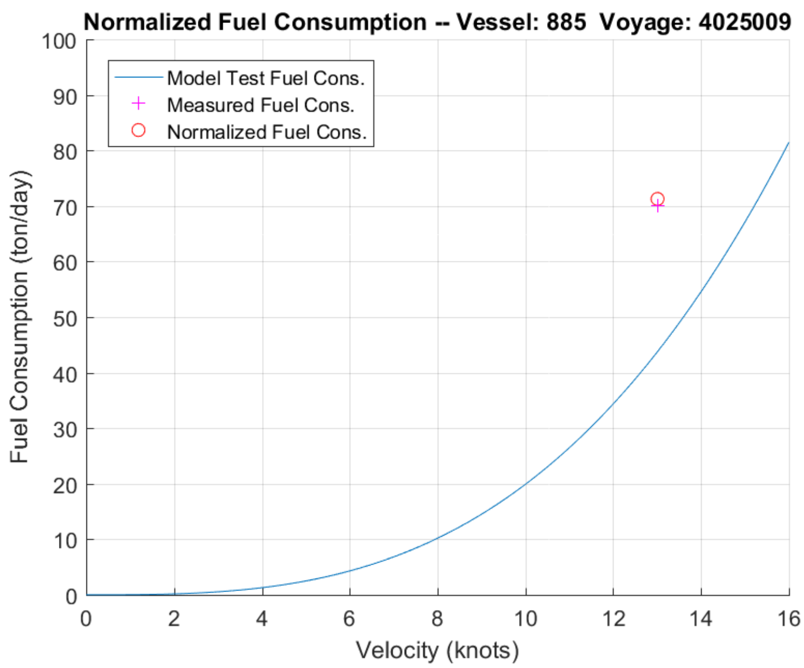
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to maneuvering.
Noon Report 15 filtered out due to maneuvering.
Noon Report 16 filtered out due to maneuvering.
Noon Report 17 filtered out due to maneuvering.
Noon Report 18 filtered out due to maneuvering.

Noon Report 20 filtered out due to maneuvering.
Noon Report 21 filtered out due to maneuvering.
Noon Report 22 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1501L

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
3	01-Jan-2016 09:00:00	02-Jan-2016 08:00:00	20.60	72.90 40.31	0.00 42.20	0.00 42.20
4	02-Jan-2016 08:00:00	03-Jan-2016 07:00:00	20.60	72.70 40.31	0.00 42.20	0.00 42.20
5	03-Jan-2016 07:00:00	04-Jan-2016 07:00:00	20.60	74.80 40.31	0.00 42.20	0.00 42.20
6	04-Jan-2016 07:00:00	05-Jan-2016 07:00:00	20.60	74.80 40.31	0.00 42.20	0.00 42.20
9	07-Jan-2016 06:00:00	08-Jan-2016 06:00:00	20.40	76.40 40.31	0.00 42.20	0.00 42.20
10	08-Jan-2016 06:00:00	09-Jan-2016 06:00:00	20.30	76.00 40.31	0.00 42.20	0.00 42.20

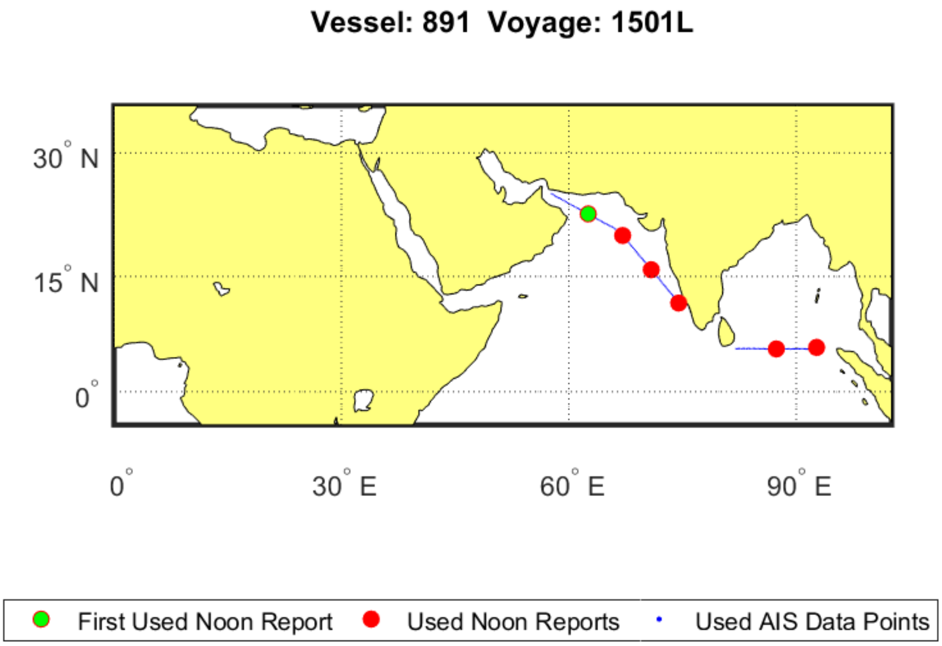
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
3	23	310	314	13.66	1865.7	72.21	
4	23	300	303	13.16	1885.8	74.08	
5	24	336	340	14.15	1805.3	72.30	
6	24	331	333	13.85	1840.8	72.25	
9	24	323	320	13.32	1919.7	72.53	
10	24	318	325	13.55	1887.1	72.36	

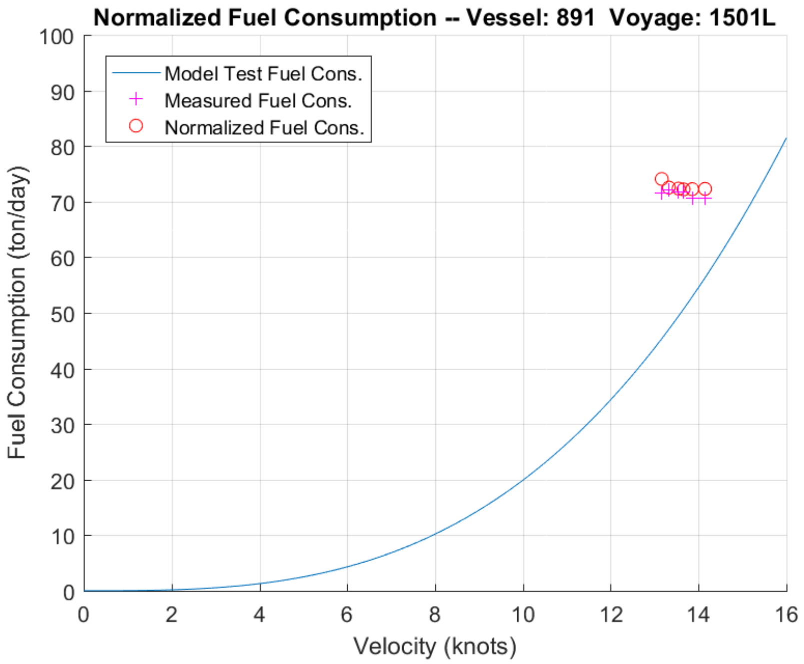
Filtered Data:

Noon Report 1 filtered out due to maneuvering.
Noon Report 2 filtered out due to maneuvering.
Noon Report 7 filtered out due to maneuvering.
Noon Report 8 filtered out due to maneuvering.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1602 / 0011

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
10	01-Apr-2016 10:00:00	01-Apr-2016 14:00:00	21.80	15.50 40.31	0.00 42.20	0.00 42.20

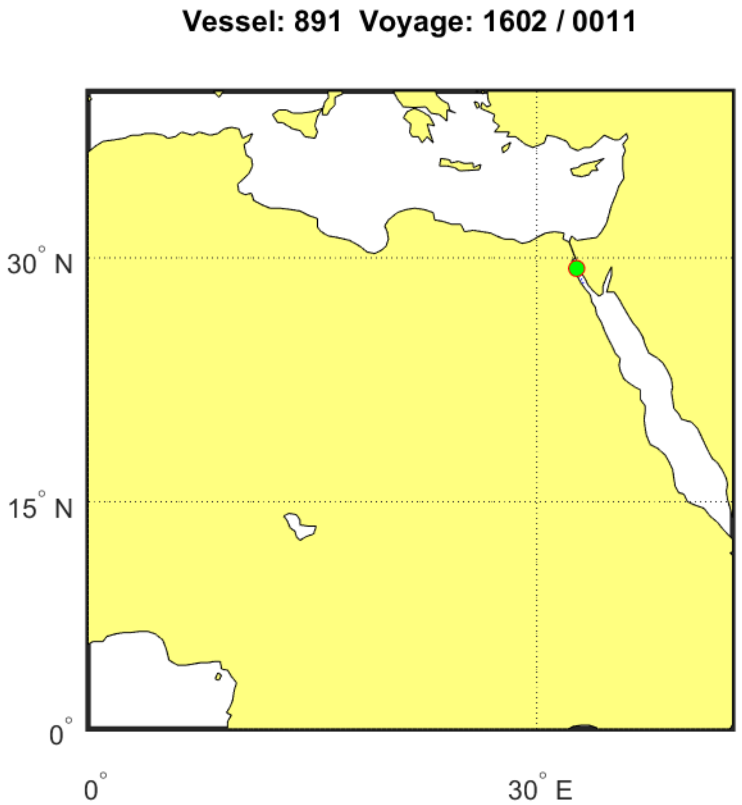
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
10	4	52	52	13.04	2305.6	85.11	**

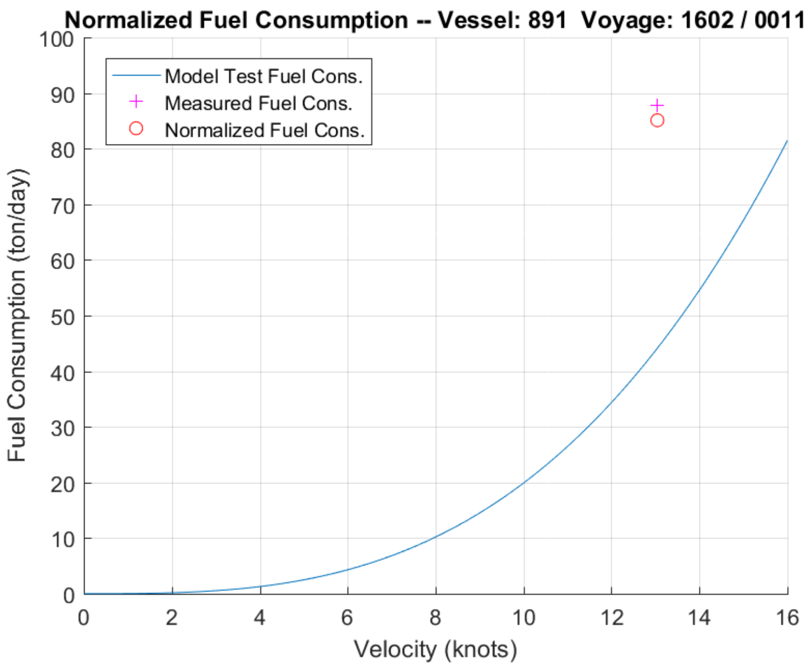
Filtered Data:

Noon Report 7 filtered out due to acceleration.
Noon Report 1 filtered out due to maneuvering.
Noon Report 2 filtered out due to maneuvering.
Noon Report 3 filtered out due to maneuvering.
Noon Report 4 filtered out due to maneuvering.
Noon Report 5 filtered out due to maneuvering.
Noon Report 8 filtered out due to maneuvering.
Noon Report 9 filtered out due to maneuvering.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1603/0012 SHELL VOY

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
5	15-May-2016 07:00:00	16-May-2016 07:00:00	20.50	68.10 40.31	0.00 42.20	0.00 42.20
10	20-May-2016 06:00:00	21-May-2016 06:00:00	20.40	56.20 40.31	0.00 42.20	0.00 42.20
11	21-May-2016 06:00:00	22-May-2016 05:00:00	20.40	51.30 40.31	0.00 42.20	0.00 42.20

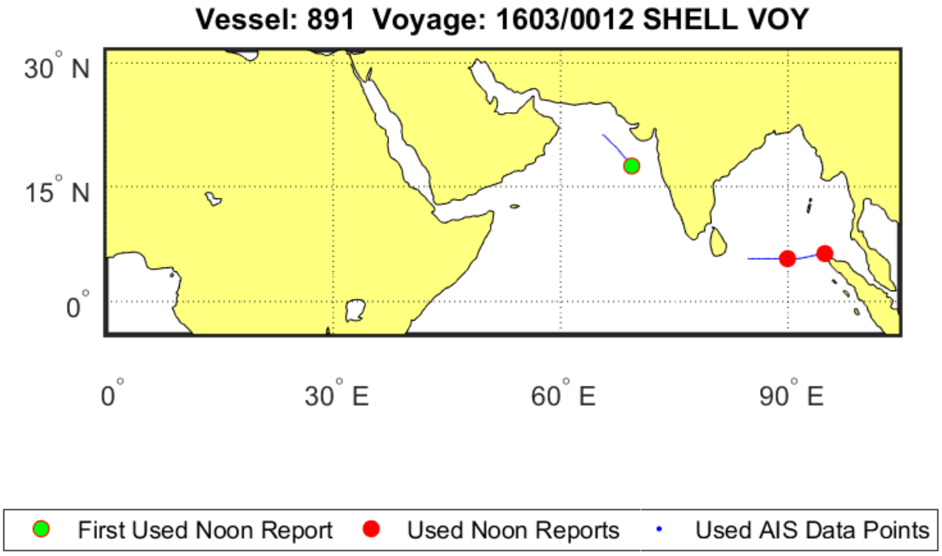
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
5	24	325	319	13.30	1771.2	66.77	
10	24	312	291	12.13	1629.9	56.18	
11	23	297	288	12.50	1496.5	53.15	

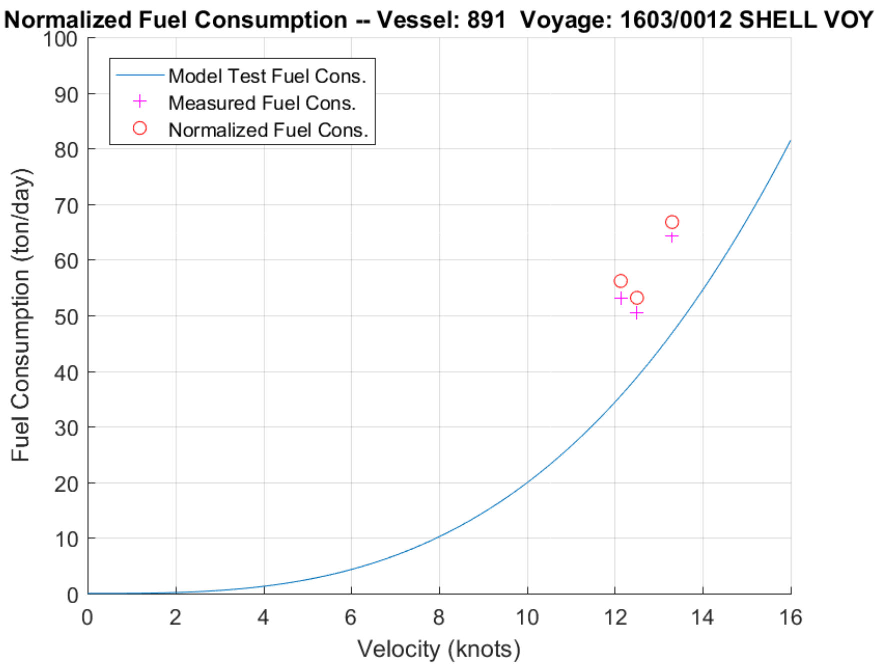
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to maneuvering.
Noon Report 3 filtered out due to maneuvering.
Noon Report 4 filtered out due to maneuvering.
Noon Report 8 filtered out due to maneuvering.
Noon Report 9 filtered out due to maneuvering.
Noon Report 12 filtered out due to maneuvering.
Noon Report 13 filtered out due to maneuvering.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1605/0014

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
6	07-Sep-2016 10:00:00	08-Sep-2016 10:00:00	22.00	25.40 40.31	0.00 42.20	0.00 42.20
12	13-Sep-2016 10:00:00	14-Sep-2016 10:00:00	22.00	26.70 40.31	0.00 42.20	0.00 42.20
14	15-Sep-2016 10:00:00	16-Sep-2016 10:00:00	22.00	26.10 40.31	0.00 42.20	0.00 42.20

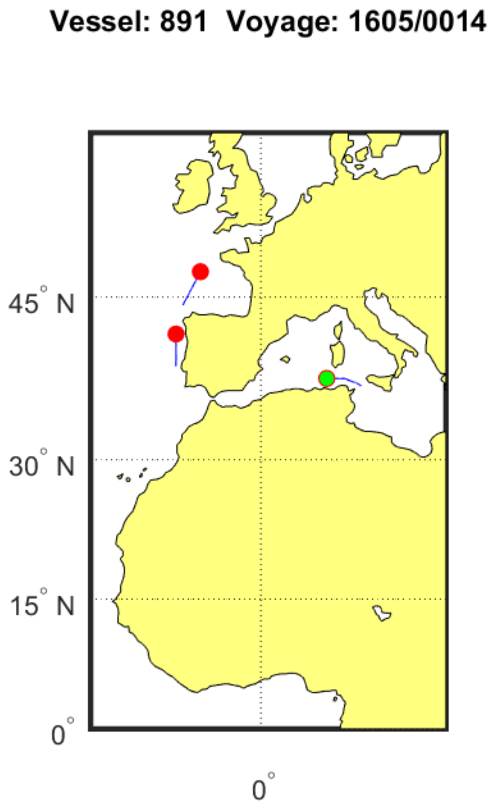
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
6	24	201	206	8.57	959.1	23.58	**
12	24	170	176	7.31	1200.2	24.99	
14	24	184	188	7.82	916.1	20.79	

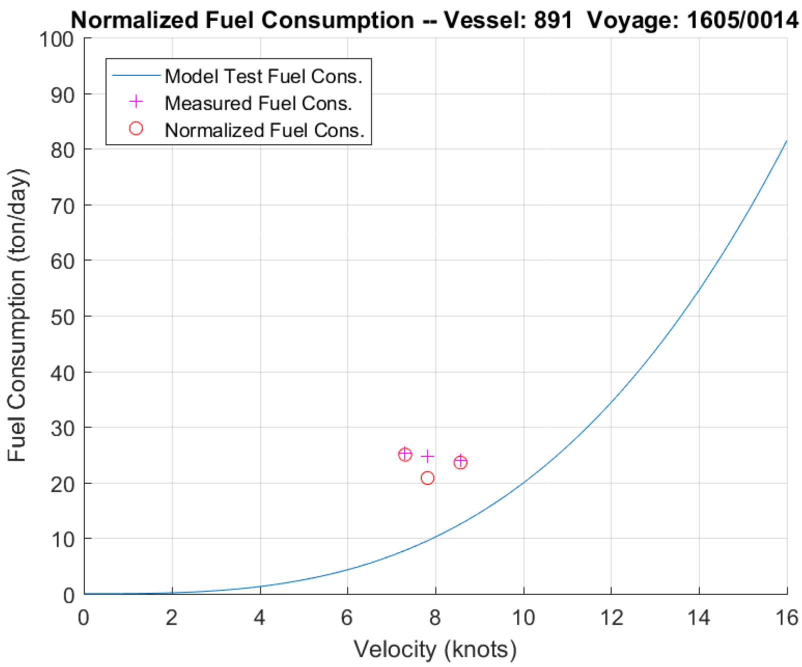
Filtered Data:

Noon Report 15 filtered out manually.
Noon Report 13 filtered out due to acceleration.
Noon Report 1 filtered out due to maneuvering.
Noon Report 2 filtered out due to maneuvering.
Noon Report 3 filtered out due to maneuvering.
Noon Report 4 filtered out due to maneuvering.
Noon Report 5 filtered out due to maneuvering.
Noon Report 8 filtered out due to maneuvering.
Noon Report 9 filtered out due to maneuvering.
Noon Report 10 filtered out due to maneuvering.
Noon Report 11 filtered out due to maneuvering.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1607/0015

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
10	17-Oct-2016 11:00:00	18-Oct-2016 12:00:00	20.50	73.80 40.31	0.00 42.20	0.00 42.20
11	18-Oct-2016 12:00:00	19-Oct-2016 12:00:00	20.50	71.90 40.31	0.00 42.20	0.00 42.20
13	20-Oct-2016 12:00:00	21-Oct-2016 12:00:00	20.50	70.60 40.31	0.00 42.20	0.00 42.20
14	21-Oct-2016 12:00:00	22-Oct-2016 12:00:00	20.50	70.40 40.31	0.00 42.20	0.00 42.20
15	22-Oct-2016 12:00:00	23-Oct-2016 12:00:00	20.50	70.30 40.31	0.00 42.20	0.00 42.20
18	25-Oct-2016 12:00:00	26-Oct-2016 12:00:00	20.50	71.80 40.31	0.00 42.20	0.00 42.20
19	26-Oct-2016 12:00:00	27-Oct-2016 12:00:00	20.50	71.80 40.31	0.00 42.20	0.00 42.20
20	27-Oct-2016 12:00:00	28-Oct-2016 11:00:00	20.50	68.50 40.31	0.00 42.20	0.00 42.20
21	28-Oct-2016 11:00:00	29-Oct-2016 11:00:00	20.50	71.90 40.31	0.00 42.20	0.00 42.20
24	31-Oct-2016 11:00:00	01-Nov-2016 10:00:00	20.50	67.50 40.31	0.00 42.20	0.00 42.20
26	02-Nov-2016 10:00:00	03-Nov-2016 10:00:00	20.50	69.20 40.31	0.00 42.20	0.00 42.20
29	05-Nov-2016 09:00:00	06-Nov-2016 09:00:00	20.50	70.20 40.31	0.00 42.20	0.00 42.20
30	06-Nov-2016 09:00:00	07-Nov-2016 09:00:00	20.50	70.80 40.31	0.00 42.20	0.00 42.20
31	07-Nov-2016 09:00:00	08-Nov-2016 08:00:00	20.50	68.50 40.31	0.00 42.20	0.00 42.20

32	08-Nov-2016 08:00:00	09-Nov-2016 08:00:00	20.50	69.80 40.31	0.00 42.20	0.00 42.20
33	09-Nov-2016 08:00:00	10-Nov-2016 08:00:00	20.50	70.10 40.31	0.00 42.20	0.00 42.20
34	10-Nov-2016 08:00:00	11-Nov-2016 07:00:00	20.50	68.30 40.31	0.00 42.20	0.00 42.20
38	14-Nov-2016 07:00:00	15-Nov-2016 06:00:00	20.50	69.80 40.31	0.00 42.20	0.00 42.20
40	16-Nov-2016 06:00:00	17-Nov-2016 05:00:00	20.50	68.60 40.31	0.00 42.20	0.00 42.20
42	18-Nov-2016 05:00:00	19-Nov-2016 04:00:00	20.50	60.50 40.31	0.00 42.20	0.00 42.20
48	24-Nov-2016 04:00:00	25-Nov-2016 04:00:00	20.25	63.40 40.31	0.00 42.20	0.00 42.20
50	26-Nov-2016 04:00:00	27-Nov-2016 04:00:00	20.25	71.80 40.31	0.00 42.20	0.00 42.20

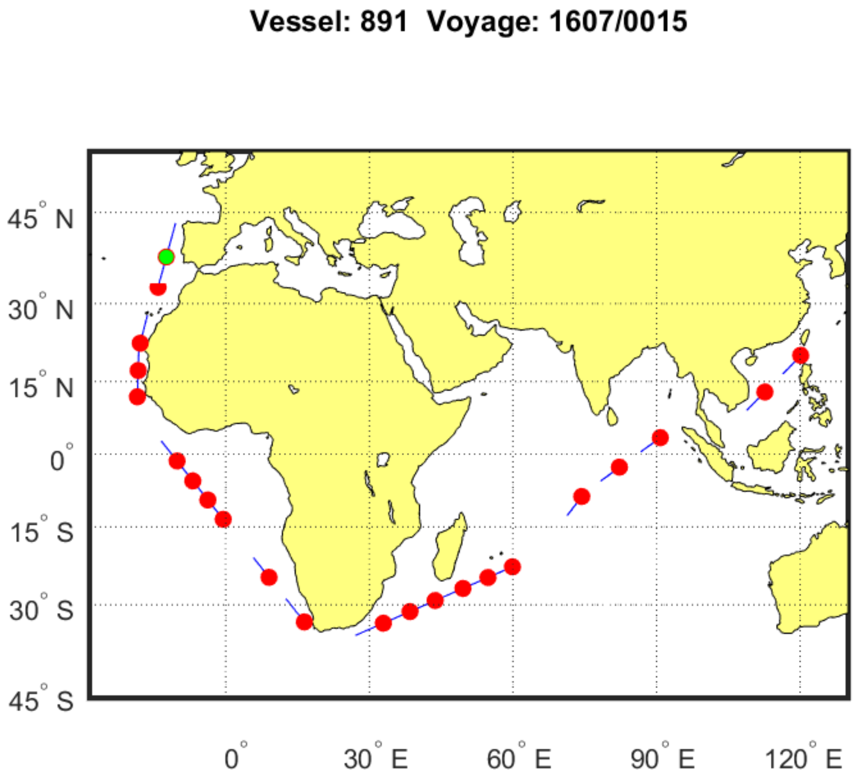
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
10	25	333	335	13.40	1704.0	64.70	
11	24	319	320	13.31	1806.5	68.10	
13	24	324	323	13.48	1795.2	68.53	
14	24	322	320	13.34	1812.5	68.51	
15	24	316	320	13.34	1821.2	68.75	
18	24	316	311	12.97	1854.0	68.08	
19	24	316	314	13.09	1820.2	67.45	
20	23	299	302	13.15	1809.1	67.41	
21	24	301	300	12.49	1894.0	66.97	
24	23	286	288	12.53	1781.2	63.17	
26	24	317	317	13.22	1733.5	65.00	
29	24	314	319	13.30	1787.2	67.34	
30	24	307	313	13.04	1807.3	66.95	
31	23	297	298	12.95	1856.5	68.17	
32	24	334	322	13.41	1742.7	66.53	
33	24	306	316	13.17	1773.4	66.25	
34	23	306	305	13.27	1788.4	67.21	
38	23	291	300	13.16	1898.1	70.68	
40	23	288	302	13.13	1851.7	69.03	
42	23	303	300	13.06	1682.5	62.25	
48	24	316	314	13.08	1576.9	58.79	
50	24	304	308	12.83	1619.8	58.92	

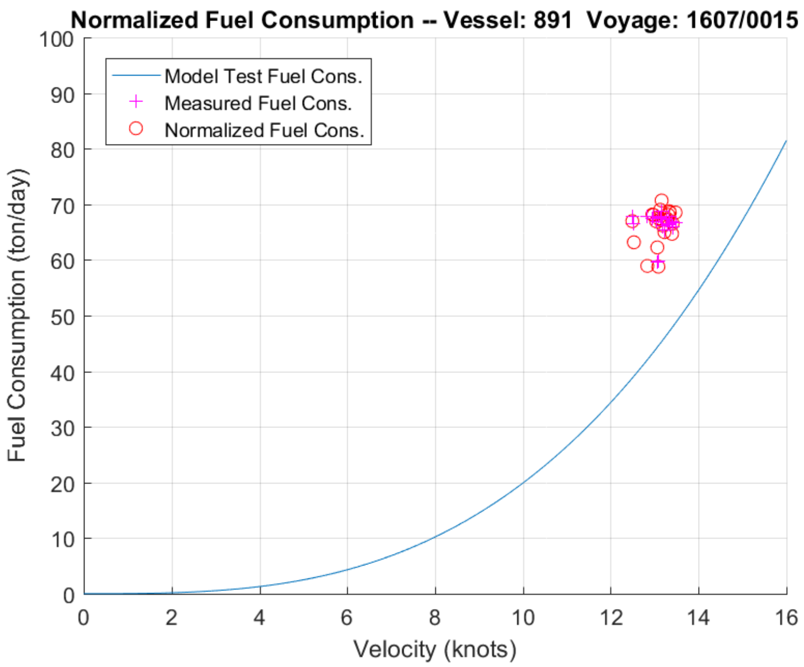
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to fuel use.
Noon Report 5 filtered out due to fuel use.
Noon Report 6 filtered out due to fuel use.
Noon Report 7 filtered out due to fuel use.
Noon Report 22 filtered out due to acceleration.
Noon Report 8 filtered out due to maneuvering.
Noon Report 9 filtered out due to maneuvering.
Noon Report 12 filtered out due to maneuvering.
Noon Report 16 filtered out due to maneuvering.
Noon Report 17 filtered out due to maneuvering.
Noon Report 27 filtered out due to maneuvering.
Noon Report 28 filtered out due to maneuvering.
Noon Report 35 filtered out due to maneuvering.
Noon Report 36 filtered out due to maneuvering.
Noon Report 39 filtered out due to maneuvering.
Noon Report 41 filtered out due to maneuvering.
Noon Report 43 filtered out due to maneuvering.
Noon Report 44 filtered out due to maneuvering.
Noon Report 45 filtered out due to maneuvering.
Noon Report 46 filtered out due to maneuvering.
Noon Report 47 filtered out due to maneuvering.
Noon Report 49 filtered out due to maneuvering.
Noon Report 51 filtered out due to maneuvering.
Noon Report 52 filtered out due to maneuvering.
Noon Report 53 filtered out due to maneuvering.
Noon Report 54 filtered out due to maneuvering.
Noon Report 23 filtered out due to inconsistent AIS/NR lengths.
Noon Report 25 filtered out due to inconsistent AIS/NR lengths.
Noon Report 37 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 16

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
4	09-Apr-2016 11:00:00	10-Apr-2016 11:00:00	11.60	26.00 41.26	0.00 42.20	0.00 42.20
5	10-Apr-2016 11:00:00	11-Apr-2016 11:00:00	11.60	26.00 41.26	0.00 42.20	0.00 42.20
6	11-Apr-2016 11:00:00	12-Apr-2016 11:00:00	11.60	30.50 41.26	0.00 42.20	0.00 42.20
8	13-Apr-2016 11:00:00	14-Apr-2016 11:00:00	11.60	33.50 41.26	0.00 42.20	0.00 42.20

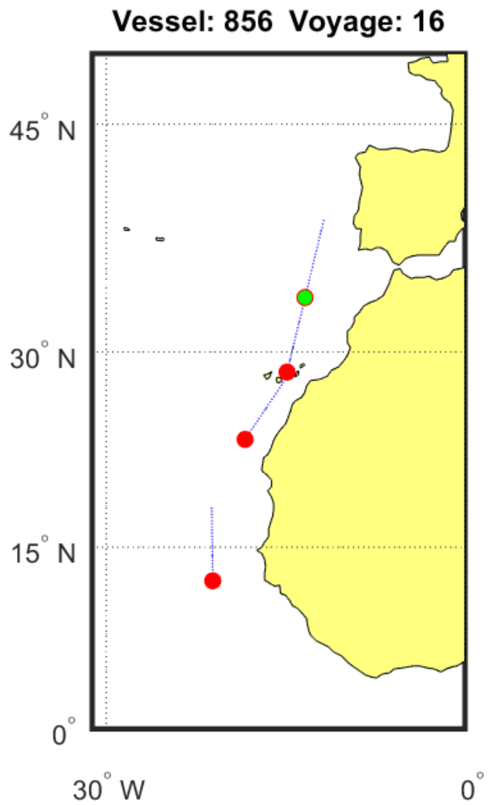
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
4	24	323	322	13.47	578.2	25.01	
5	24	326	324	13.52	573.3	24.91	
6	24	356	355	14.82	606.8	28.96	
8	24	356	355	14.81	692.7	32.97	

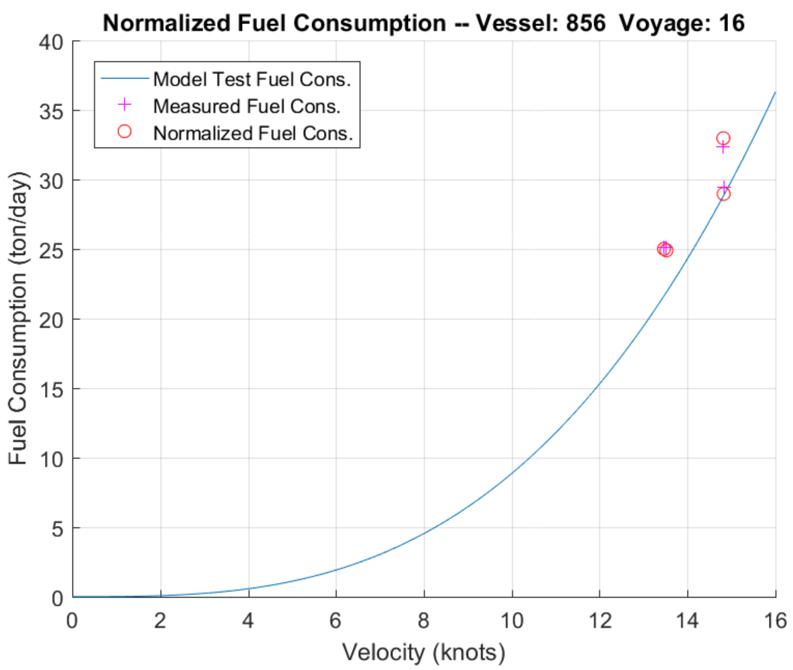
Filtered Data:

Noon Report 2 filtered out manually.
Noon Report 7 filtered out due to maneuvering.
Noon Report 9 filtered out due to maneuvering.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 10 filtered out due to lack of AIS data.
Noon Report 11 filtered out due to lack of AIS data.
Noon Report 12 filtered out due to lack of AIS data.
Noon Report 13 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 17

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
25	28-May-2016 10:00:00	29-May-2016 10:00:00	12.40	23.00 41.26	0.00 42.20	0.00 42.20
26	29-May-2016 10:00:00	30-May-2016 10:00:00	12.40	27.60 41.26	0.00 42.20	0.00 42.20
29	01-Jun-2016 11:00:00	02-Jun-2016 11:00:00	12.40	26.30 41.26	0.00 42.20	0.00 42.20
31	03-Jun-2016 12:00:00	04-Jun-2016 12:00:00	12.40	26.00 41.26	0.00 42.20	0.00 42.20
32	04-Jun-2016 12:00:00	05-Jun-2016 12:00:00	12.40	27.00 41.26	0.00 42.20	0.00 42.20
33	05-Jun-2016 12:00:00	06-Jun-2016 13:00:00	12.40	28.50 41.26	0.00 42.20	0.00 42.20
34	06-Jun-2016 13:00:00	07-Jun-2016 13:00:00	12.40	27.20 41.26	0.00 42.20	0.00 42.20
35	07-Jun-2016 13:00:00	08-Jun-2016 13:00:00	12.40	27.10 41.26	0.00 42.20	0.00 42.20
37	09-Jun-2016 14:00:00	10-Jun-2016 14:00:00	12.40	26.80 41.26	0.00 42.20	0.00 42.20
38	10-Jun-2016 14:00:00	11-Jun-2016 14:00:00	12.40	29.90 41.26	0.00 42.20	0.00 42.20
40	12-Jun-2016 15:00:00	13-Jun-2016 15:00:00	12.40	30.00 41.26	0.00 42.20	0.00 42.20
41	13-Jun-2016 15:00:00	14-Jun-2016 15:00:00	12.40	28.40 41.26	0.00 42.20	0.00 42.20

AIS Calculated Data:

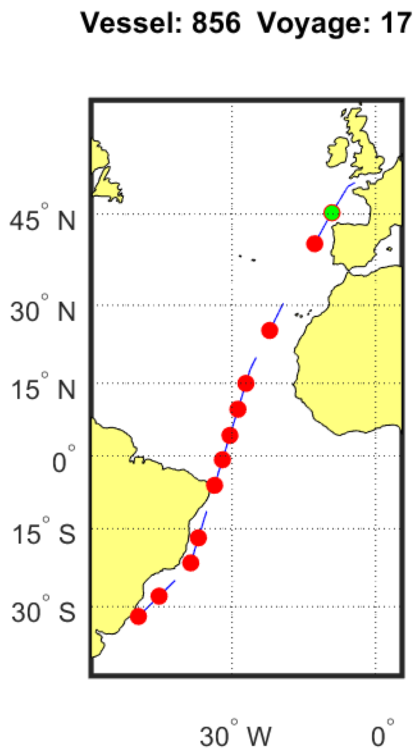
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
25	24	326	325	13.60	421.0	18.48	
26	24	323	323	13.68	532.9	23.43	
29	24	332	332	13.87	529.5	23.59	
31	24	329	328	13.68	551.9	24.26	
32	24	329	335	13.95	554.1	24.83	
33	25	337	348	13.93	557.8	24.98	
34	24	315	324	13.52	563.5	24.52	
35	24	331	324	13.58	561.7	24.51	
37	24	330	329	13.76	516.0	22.82	
38	24	306	303	12.68	573.3	23.47	
40	24	249	249	10.38	589.2	20.00	
41	24	313	306	12.81	483.7	19.99	

Filtered Data:

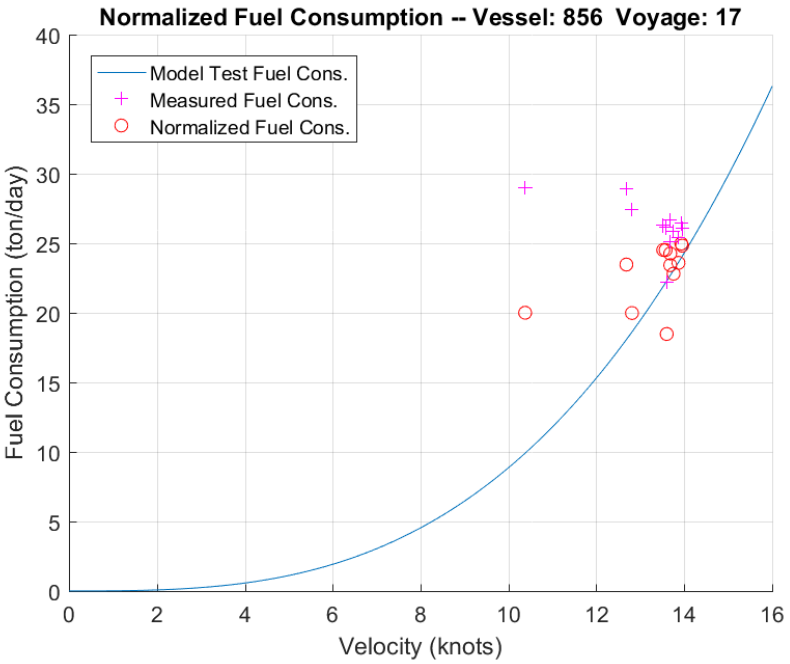
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 20 filtered out due to draft.
Noon Report 21 filtered out due to fuel use.
Noon Report 22 filtered out due to fuel use.
Noon Report 23 filtered out due to fuel use.
Noon Report 24 filtered out due to fuel use.
Noon Report 28 filtered out due to maneuvering.

Noon Report 39 filtered out due to maneuvering.
Noon Report 42 filtered out due to maneuvering.
Noon Report 27 filtered out due to inconsistent AIS/NR lengths.
Noon Report 30 filtered out due to inconsistent AIS/NR lengths.
Noon Report 36 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 18

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
22	17-Jul-2016 10:00:00	18-Jul-2016 10:00:00	11.07	22.60 41.26	0.00 42.20	0.00 42.20
24	19-Jul-2016 10:00:00	20-Jul-2016 10:00:00	11.07	22.60 41.26	0.00 42.20	0.00 42.20
26	21-Jul-2016 10:00:00	22-Jul-2016 11:00:00	11.07	23.20 41.26	0.00 42.20	0.00 42.20

AIS Calculated Data:

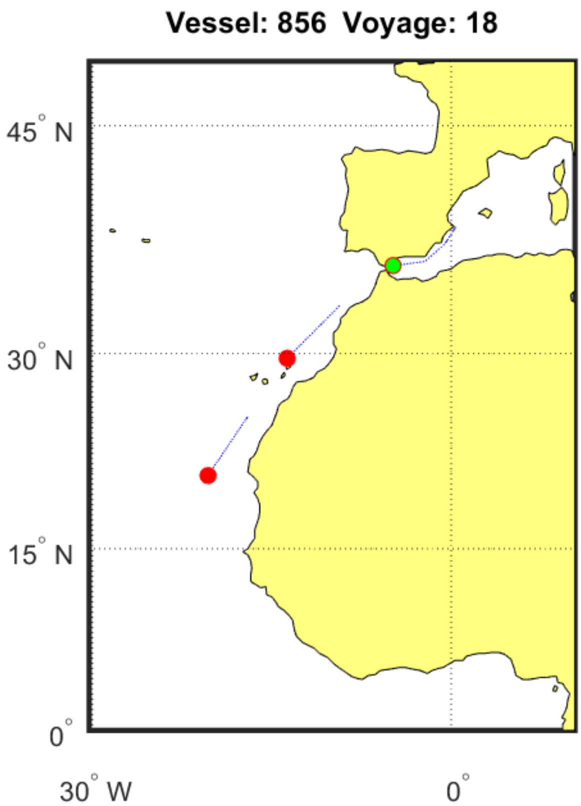
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
22	24	313	316	13.20	542.0	22.99	**
24	24	318	313	13.06	550.0	23.07	
26	25	323	320	12.83	536.6	22.14	

Filtered Data:

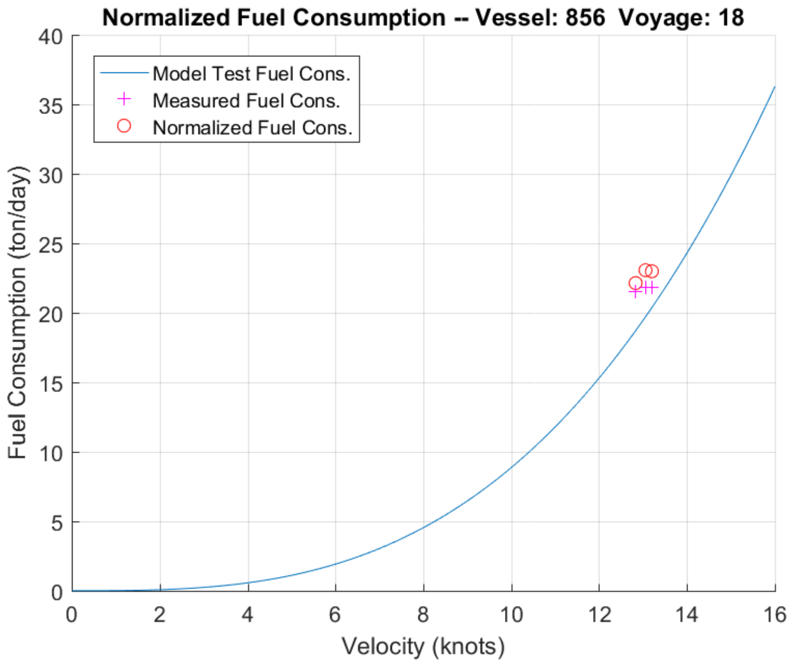
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.

Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 23 filtered out due to acceleration.
Noon Report 29 filtered out due to acceleration.
Noon Report 20 filtered out due to maneuvering.
Noon Report 25 filtered out due to maneuvering.
Noon Report 27 filtered out due to maneuvering.
Noon Report 34 filtered out due to maneuvering.
Noon Report 21 filtered out due to inconsistent AIS/NR lengths.
Noon Report 28 filtered out due to inconsistent AIS/NR lengths.
Noon Report 30 filtered out due to inconsistent AIS/NR lengths.
Noon Report 20 filtered out due to lack of AIS data.
Noon Report 31 filtered out due to lack of AIS data.
Noon Report 32 filtered out due to lack of AIS data.
Noon Report 33 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 22

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
8	12-Nov-2016 12:00:00	13-Nov-2016 12:00:00	11.10	24.30 41.26	0.00 42.20	0.00 42.20
10	14-Nov-2016 13:00:00	15-Nov-2016 13:00:00	11.10	24.70 41.26	0.00 42.20	0.00 42.20
11	15-Nov-2016 13:00:00	16-Nov-2016 14:00:00	11.10	25.70 41.26	0.00 42.20	0.00 42.20
12	16-Nov-2016 14:00:00	17-Nov-2016 14:00:00	11.10	24.80 41.26	0.00 42.20	0.00 42.20
13	17-Nov-2016 14:00:00	18-Nov-2016 15:00:00	11.10	24.60 41.26	0.00 42.20	0.00 42.20
19	09-Dec-2016 17:00:00	10-Dec-2016 17:00:00	11.12	21.00 41.26	0.00 42.20	0.00 42.20
20	10-Dec-2016 17:00:00	11-Dec-2016 17:00:00	11.12	21.50 41.26	0.00 42.20	0.00 42.20

AIS Calculated Data:

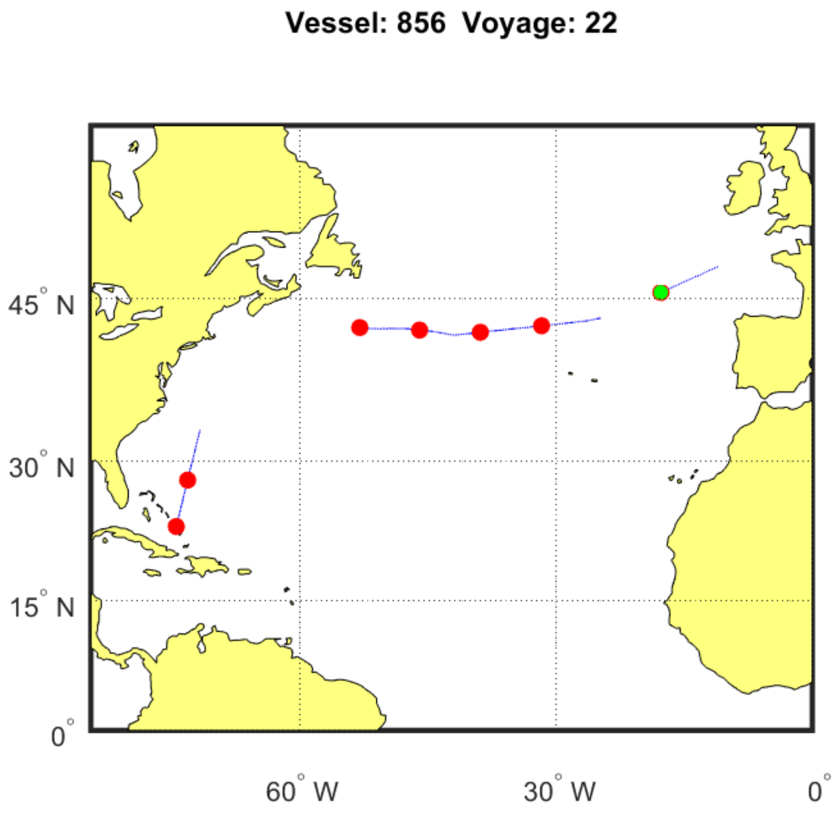
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
8	24	304	303	12.65	436.5	17.74	
10	24	307	308	13.00	493.6	20.63	
11	25	315	323	12.98	505.9	21.12	
12	24	319	323	13.52	555.9	24.16	
13	25	310	315	12.65	562.3	23.02	
19	24	311	304	12.68	528.7	21.53	
20	24	300	301	12.61	545.0	22.17	

Filtered Data:

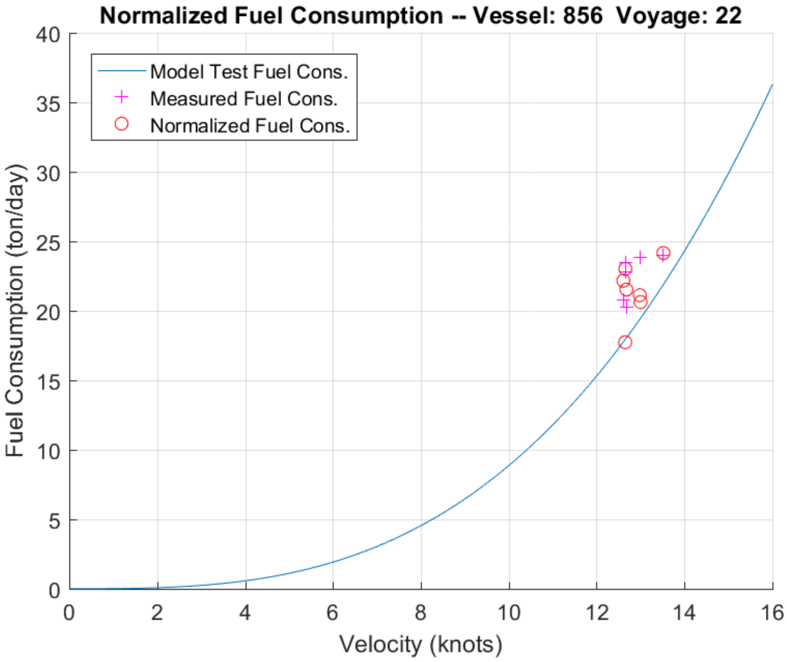
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to fuel use.
Noon Report 3 filtered out due to fuel use.

Noon Report 4 filtered out due to fuel use.
Noon Report 5 filtered out due to fuel use.
Noon Report 6 filtered out due to fuel use.
Noon Report 15 filtered out due to fuel use.
Noon Report 16 filtered out due to fuel use.
Noon Report 17 filtered out due to fuel use.
Noon Report 23 filtered out due to acceleration.
Noon Report 7 filtered out due to maneuvering.
Noon Report 14 filtered out due to maneuvering.
Noon Report 18 filtered out due to maneuvering.
Noon Report 21 filtered out due to maneuvering.
Noon Report 24 filtered out due to maneuvering.
Noon Report 25 filtered out due to maneuvering.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 22 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1507

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
5	04-Jul-2015 17:00:00	05-Jul-2015 17:00:00	11.75	25.20 40.30	0.00 42.20	0.00 42.20
9	09-Jul-2015 17:00:00	10-Jul-2015 17:00:00	11.75	23.90 40.30	0.00 42.20	0.00 42.20
10	10-Jul-2015 17:00:00	11-Jul-2015 17:00:00	11.75	24.50 40.30	0.00 42.20	0.00 42.20
11	11-Jul-2015 17:00:00	12-Jul-2015 17:00:00	11.75	20.50 40.30	0.00 42.20	0.00 42.20

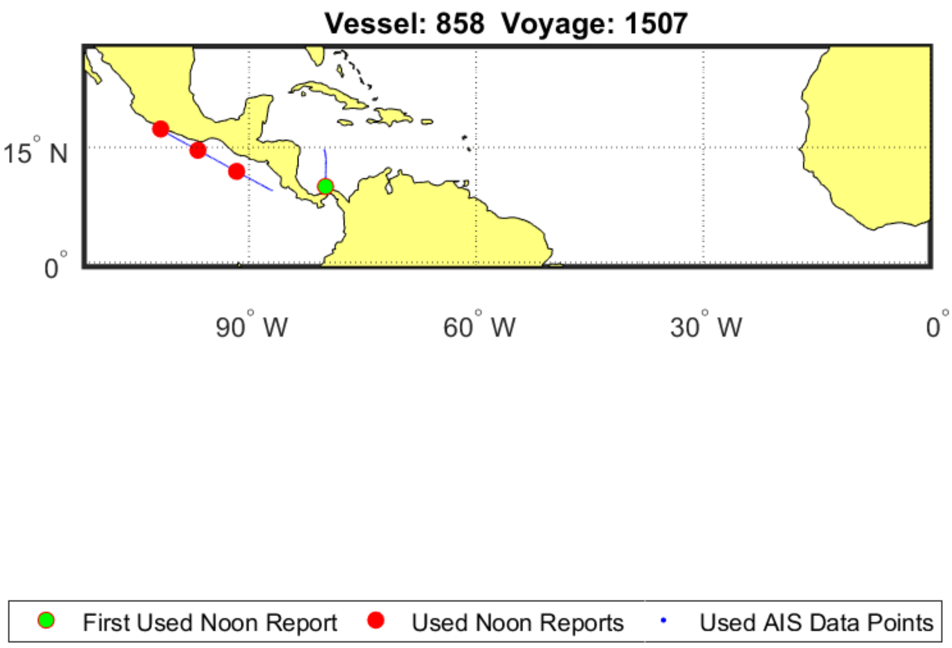
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
5	24	300	301	12.56	594.6	24.07	
9	24	332	314	13.11	533.6	22.53	
10	24	339	331	13.80	539.3	23.93	
11	24	325	302	12.62	496.2	20.21	

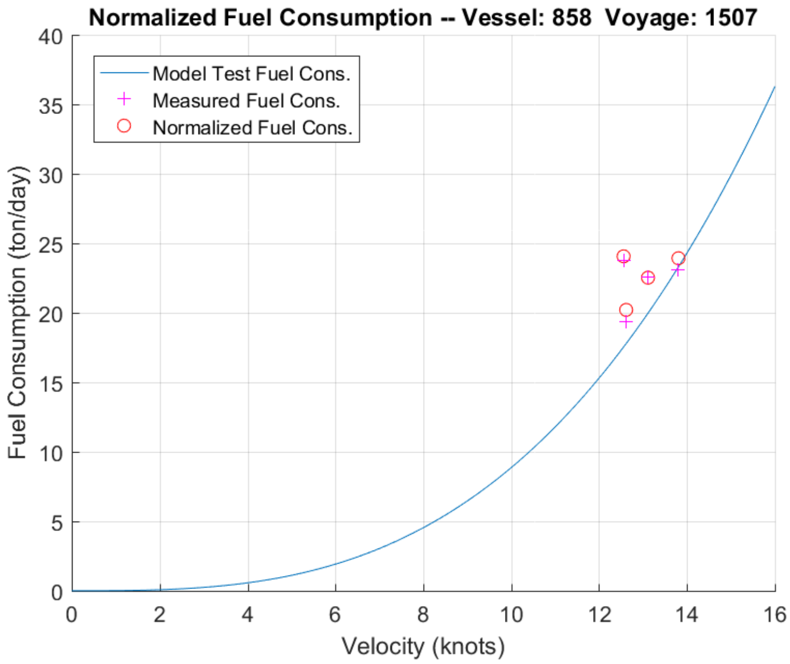
Filtered Data:

Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 20 filtered out due to draft.
Noon Report 21 filtered out due to draft.
Noon Report 22 filtered out due to draft.
Noon Report 23 filtered out due to draft.
Noon Report 24 filtered out due to draft.
Noon Report 6 filtered out manually.
Noon Report 7 filtered out due to maneuvering.
Noon Report 12 filtered out due to maneuvering.
Noon Report 1 filtered out due to inconsistent AIS/NR lengths.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1508.1

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
2	09-Sep-2015 17:00:00	10-Sep-2015 18:00:00	11.85	26.50 39.00	0.00 39.00	0.00 42.20
4	11-Sep-2015 18:00:00	12-Sep-2015 18:00:00	11.85	26.90 39.00	0.00 39.00	0.00 42.20

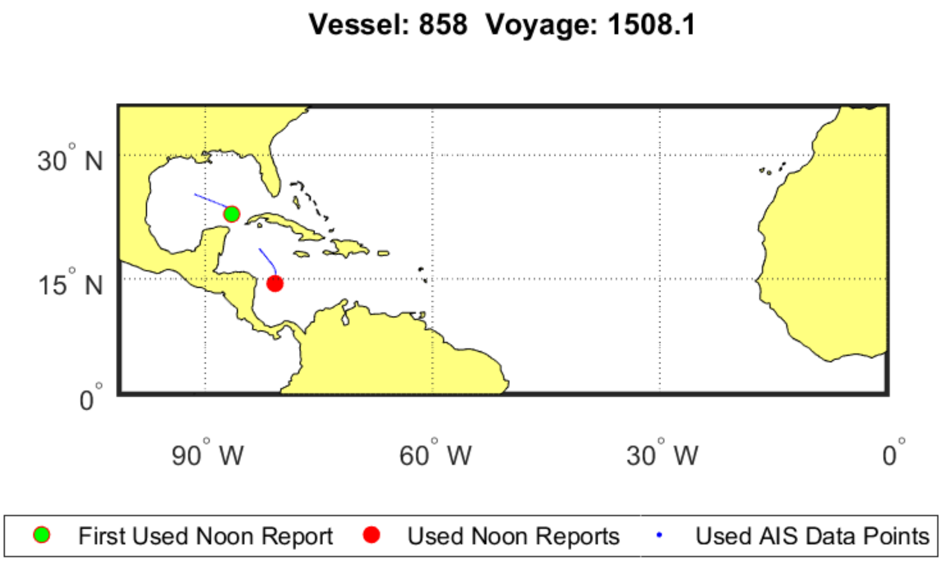
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
2	25	326	332	13.31	519.2	22.29	
4	24	310	308	12.98	563.6	23.52	

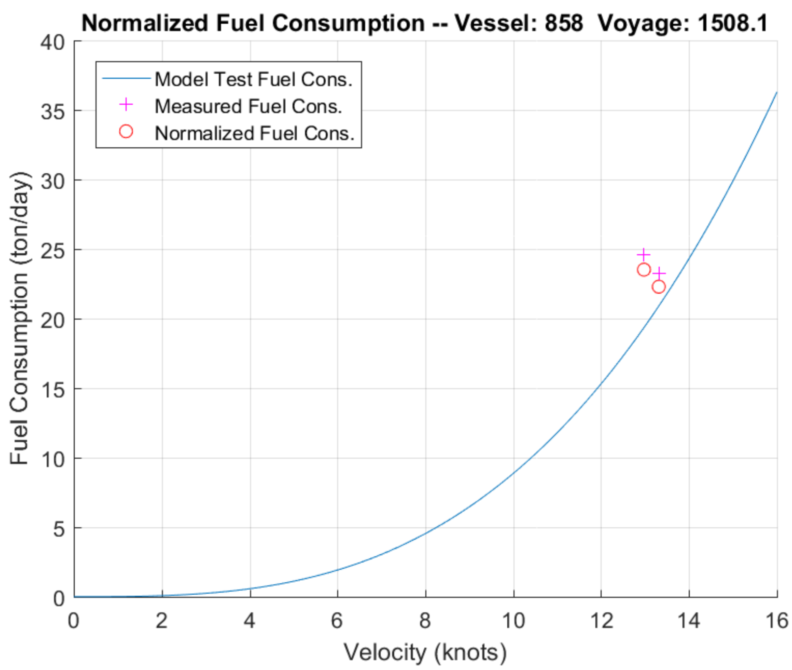
Filtered Data:

Noon Report 3 filtered out due to maneuvering.
Noon Report 5 filtered out due to maneuvering.
Noon Report 1 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1510.1

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
5	06-Oct-2015 17:00:00	07-Oct-2015 17:00:00	11.80	28.10 39.00	0.00 39.00	0.00 42.20

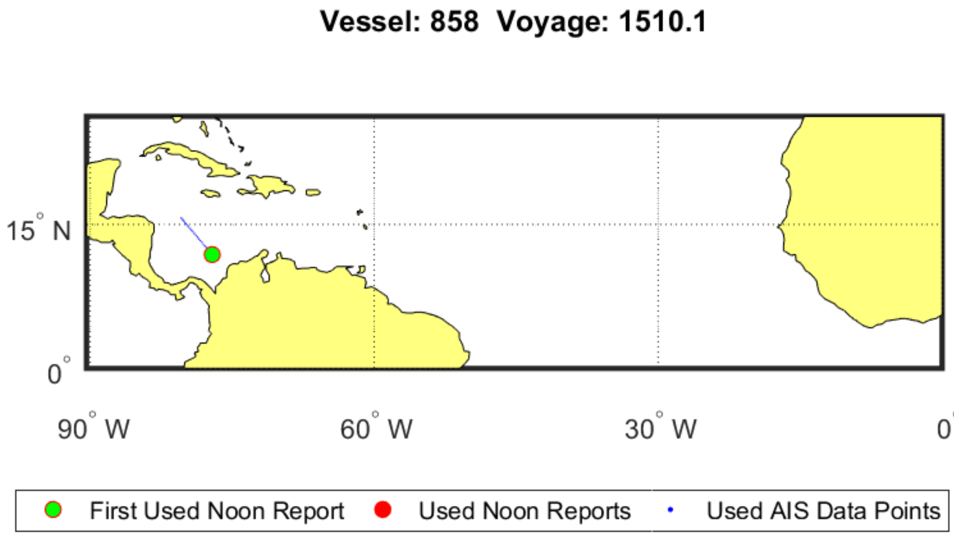
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
5	24	312	333	13.93	541.2	24.28	

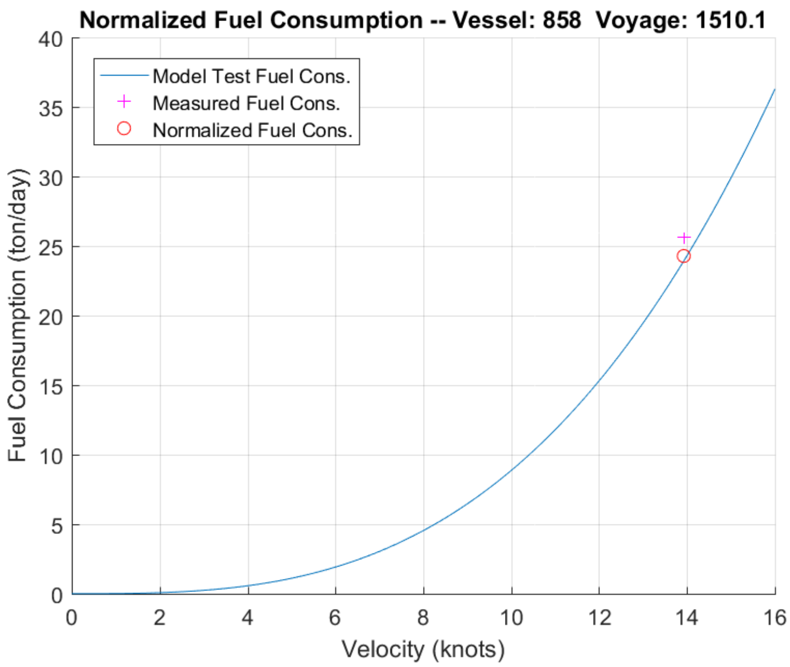
Filtered Data:

Noon Report 1 filtered out due to maneuvering.
Noon Report 6 filtered out due to maneuvering.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1511.1

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
2	27-Oct-2015 17:00:00	28-Oct-2015 17:00:00	10.60	17.70 39.00	6.00 39.00	0.00 42.20

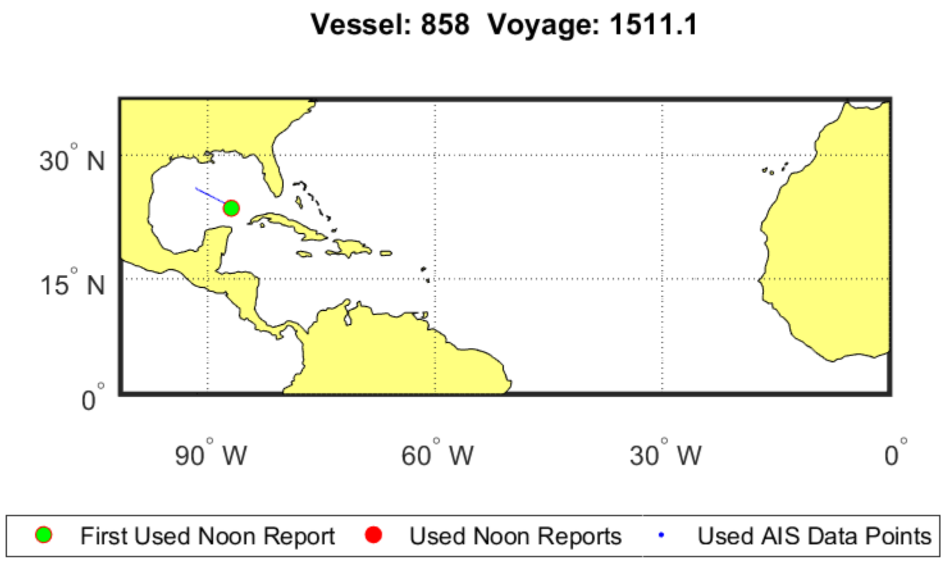
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
2	24	308	320	13.38	539.3	23.28	

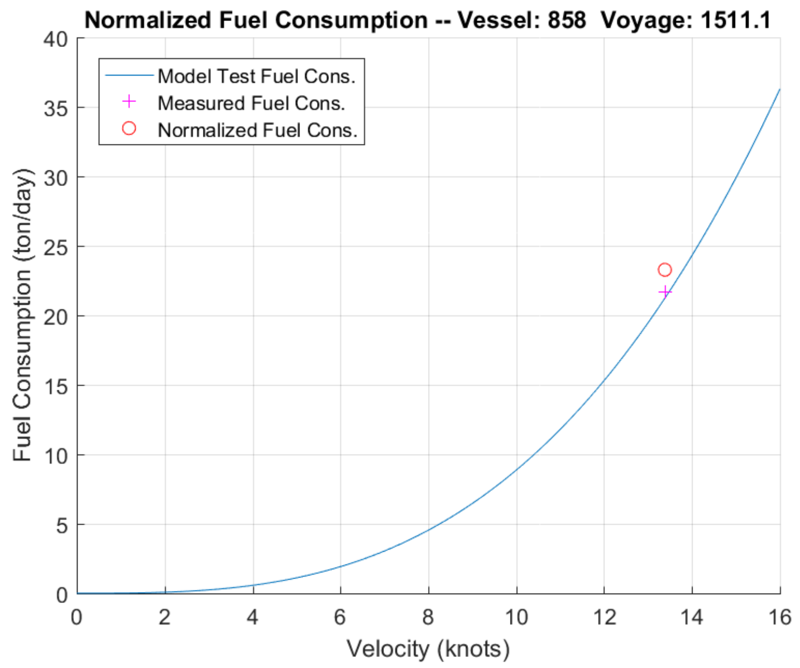
Filtered Data:

Noon Report 6 filtered out due to acceleration.
Noon Report 1 filtered out due to maneuvering.
Noon Report 4 filtered out due to maneuvering.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 5 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1513.4

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
4	16-Dec-2015 17:00:00	17-Dec-2015 17:00:00	10.25	22.60 39.00	0.00 39.00	0.00 42.20
10	23-Dec-2015 15:00:00	24-Dec-2015 15:00:00	10.25	23.20 39.00	0.00 39.00	0.00 42.20
12	25-Dec-2015 15:00:00	26-Dec-2015 15:00:00	10.25	23.00 39.00	0.00 39.00	0.00 42.20
15	28-Dec-2015 15:00:00	29-Dec-2015 15:00:00	10.25	21.30 39.00	0.00 39.00	0.00 42.20
16	29-Dec-2015 15:00:00	30-Dec-2015 15:00:00	10.25	22.20 39.00	0.00 39.00	0.00 42.20

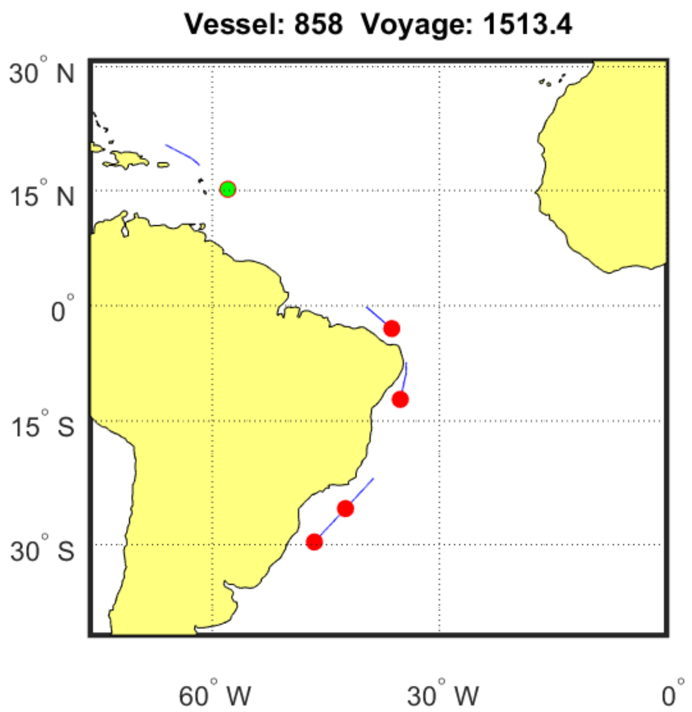
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
4	24	300	305	12.71	526.8	21.50	
10	24	274	299	12.50	536.6	21.57	
12	24	303	303	12.66	548.0	22.28	
15	24	310	311	13.00	536.7	22.45	
16	24	316	316	13.20	523.7	22.22	

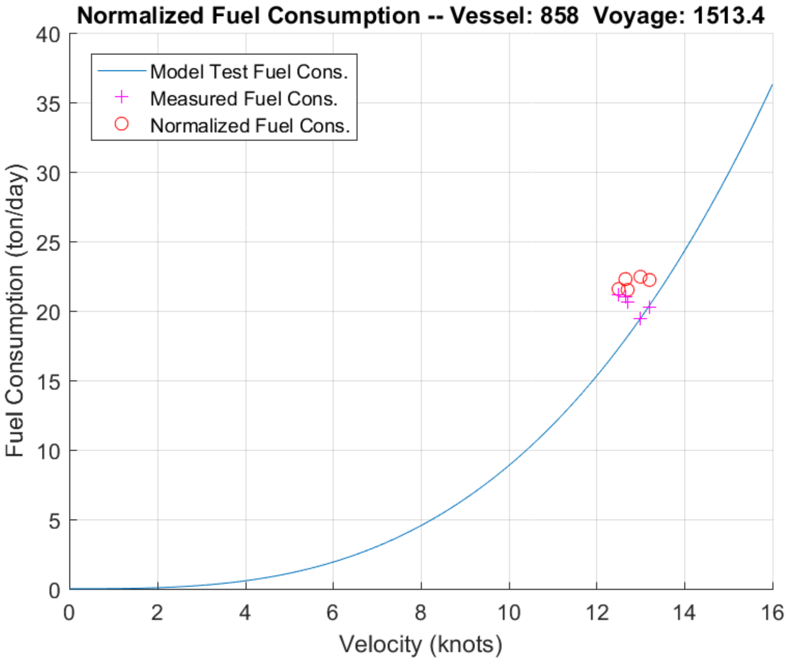
Filtered Data:

Noon Report 5 filtered out due to acceleration.
Noon Report 7 filtered out due to maneuvering.
Noon Report 8 filtered out due to maneuvering.
Noon Report 11 filtered out due to maneuvering.
Noon Report 14 filtered out due to maneuvering.
Noon Report 18 filtered out due to maneuvering.
Noon Report 1 filtered out due to inconsistent AIS/NR lengths.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 17 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 25

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
3	23-May-2016 05:00:00	23-May-2016 17:00:00	12.50	0.00 40.43	0.00 42.20	13.20 42.43
9	29-May-2016 14:00:00	30-May-2016 14:00:00	12.50	31.80 40.43	0.00 42.20	0.00 42.43
11	31-May-2016 13:00:00	01-Jun-2016 13:00:00	12.50	29.90 40.43	0.00 42.20	0.00 42.43
14	03-Jun-2016 12:00:00	04-Jun-2016 11:00:00	12.50	27.70 40.43	0.00 42.20	0.00 42.43
15	04-Jun-2016 11:00:00	05-Jun-2016 11:00:00	12.50	29.90 40.43	0.00 42.20	0.00 42.43

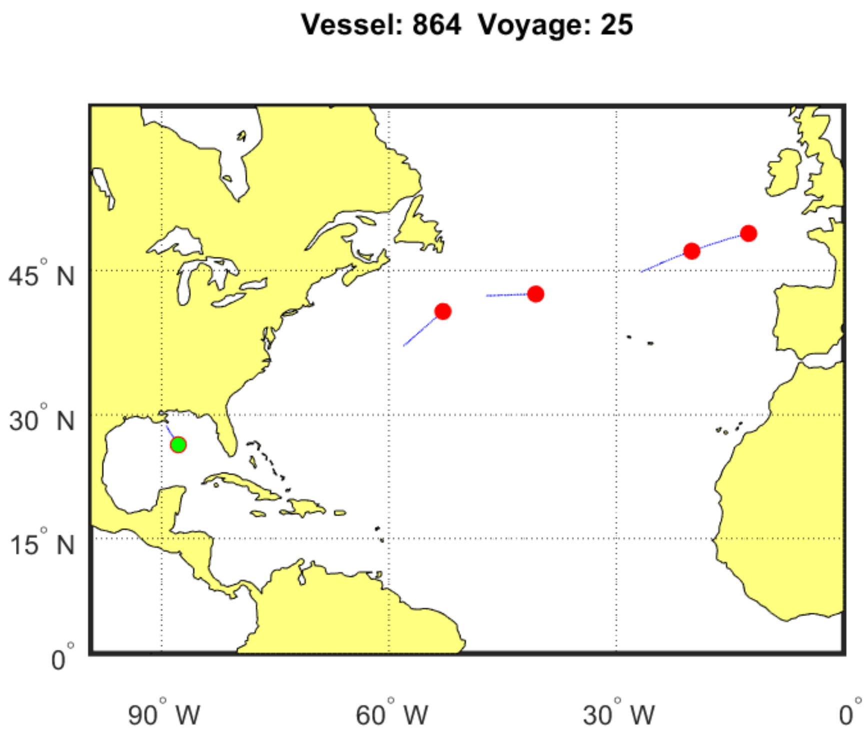
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
3	12	160	162	13.48	556.4	24.11	
9	24	323	295	12.30	620.2	24.95	
11	24	291	295	12.32	649.1	25.76	
14	23	305	305	13.28	570.0	24.94	
15	24	318	318	13.27	597.6	25.52	

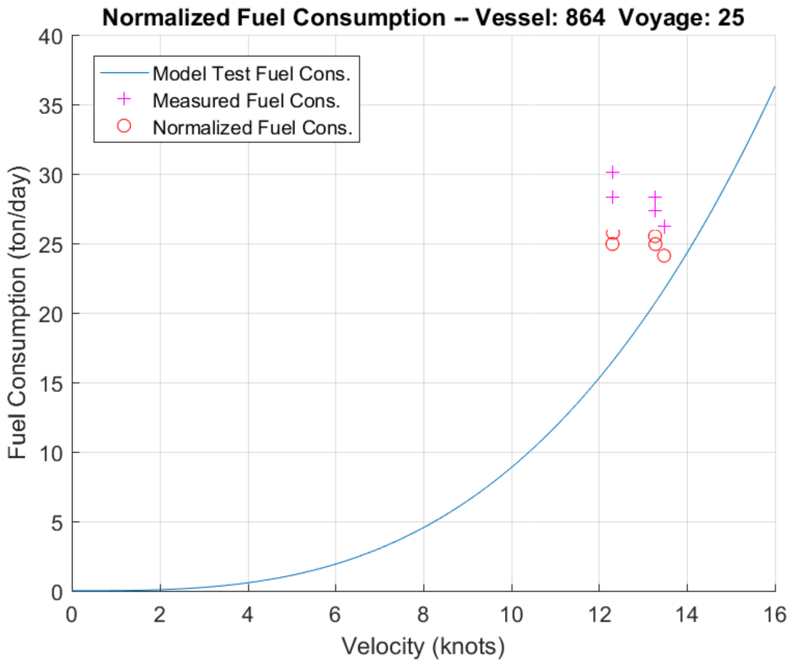
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 4 filtered out due to maneuvering.
Noon Report 5 filtered out due to maneuvering.
Noon Report 6 filtered out due to maneuvering.
Noon Report 7 filtered out due to maneuvering.
Noon Report 8 filtered out due to maneuvering.
Noon Report 10 filtered out due to maneuvering.
Noon Report 16 filtered out due to maneuvering.
Noon Report 17 filtered out due to maneuvering.
Noon Report 12 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 26

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
7	25-Jun-2016 11:00:00	26-Jun-2016 12:00:00	11.40	32.30 40.43	0.00 42.20	0.00 42.43
8	26-Jun-2016 12:00:00	27-Jun-2016 12:00:00	11.40	31.00 40.43	0.00 42.20	0.00 42.43
12	30-Jun-2016 14:00:00	01-Jul-2016 14:00:00	11.40	31.00 40.43	0.00 42.20	0.00 42.43
13	01-Jul-2016 14:00:00	02-Jul-2016 15:00:00	11.40	32.90 40.43	0.00 42.20	0.00 42.43
14	02-Jul-2016 15:00:00	03-Jul-2016 15:00:00	11.40	31.20 40.43	0.00 42.20	0.00 42.43
15	03-Jul-2016 15:00:00	04-Jul-2016 16:00:00	11.40	33.20 40.43	0.00 42.20	0.00 42.43
16	04-Jul-2016 16:00:00	05-Jul-2016 17:00:00	11.40	31.70 40.43	0.00 42.20	0.00 42.43
17	05-Jul-2016 17:00:00	06-Jul-2016 02:00:00	11.40	11.40 40.43	0.00 42.20	0.00 42.43

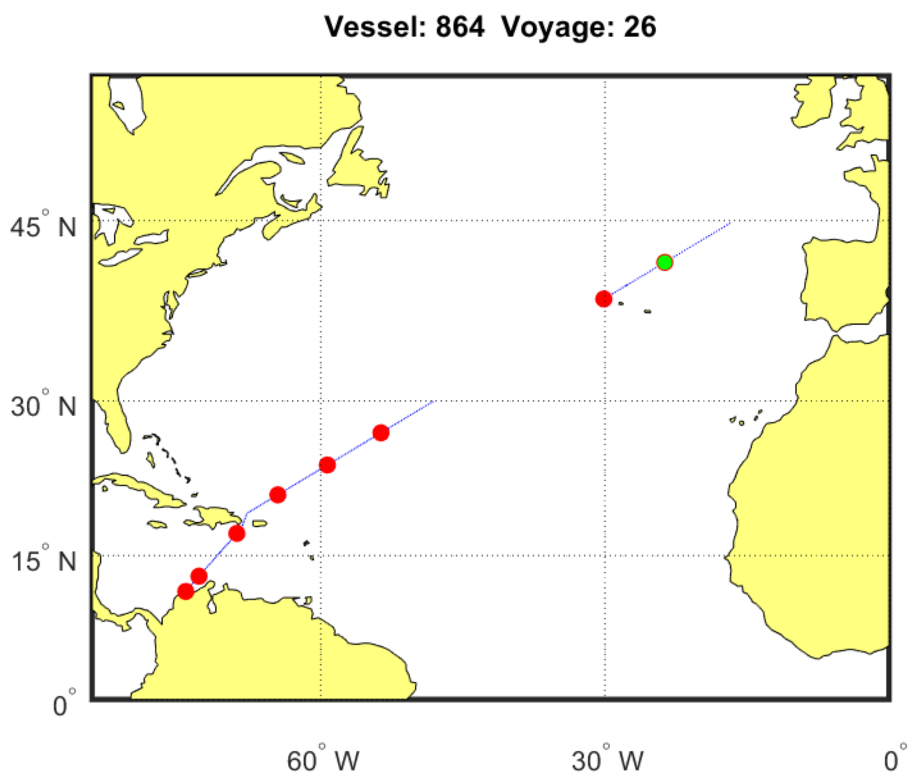
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
7	25	356	354	14.19	639.2	29.17	
8	24	342	343	14.28	627.5	28.79	
12	24	342	340	14.20	660.8	30.16	
13	25	356	357	14.32	669.9	30.82	
14	24	337	338	14.09	671.5	30.40	
15	25	349	352	14.14	682.3	31.02	
16	25	347	349	13.96	680.4	30.66	
17	9	119	117	12.96	736.6	31.20	

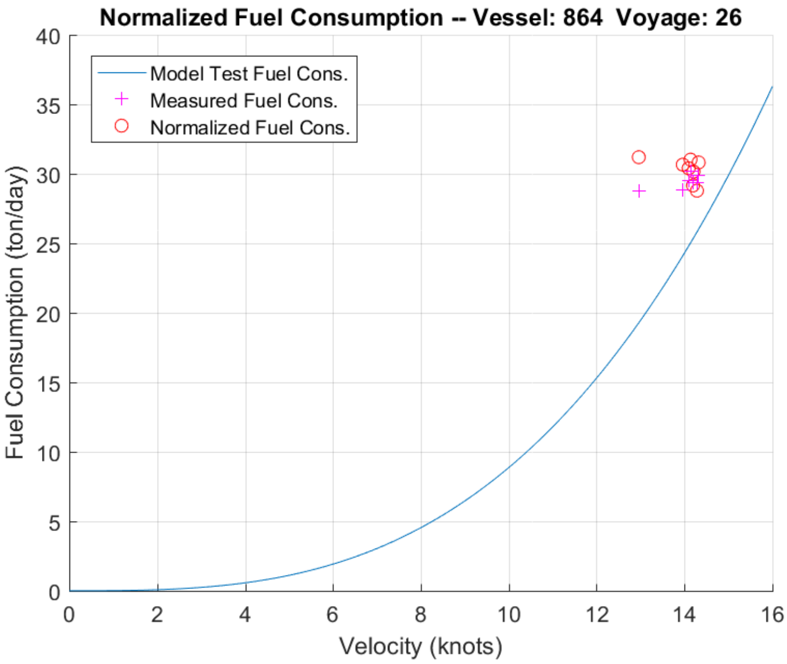
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 4 filtered out due to acceleration.
Noon Report 5 filtered out due to maneuvering.
Noon Report 10 filtered out due to maneuvering.
Noon Report 11 filtered out due to maneuvering.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 27

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
11	25-Jul-2016 15:00:00	26-Jul-2016 15:00:00	12.10	29.10 40.43	0.00 42.20	0.00 42.43
12	26-Jul-2016 15:00:00	27-Jul-2016 14:00:00	12.10	28.10 40.43	0.00 42.20	0.00 42.43
13	27-Jul-2016 14:00:00	28-Jul-2016 14:00:00	12.10	29.40 40.43	0.00 42.20	0.00 42.43
14	28-Jul-2016 14:00:00	29-Jul-2016 13:00:00	12.10	28.20 40.43	0.00 42.20	0.00 42.43
15	29-Jul-2016 13:00:00	30-Jul-2016 13:00:00	12.10	29.00 40.43	0.00 42.20	0.00 42.43
17	31-Jul-2016 12:00:00	01-Aug-2016 12:00:00	12.10	29.70 40.43	0.00 42.20	0.00 42.43
18	01-Aug-2016 12:00:00	02-Aug-2016 11:00:00	12.10	28.50 40.43	0.00 42.20	0.00 42.43
20	03-Aug-2016 11:00:00	04-Aug-2016 10:00:00	12.10	28.20 40.43	0.00 42.20	0.00 42.43

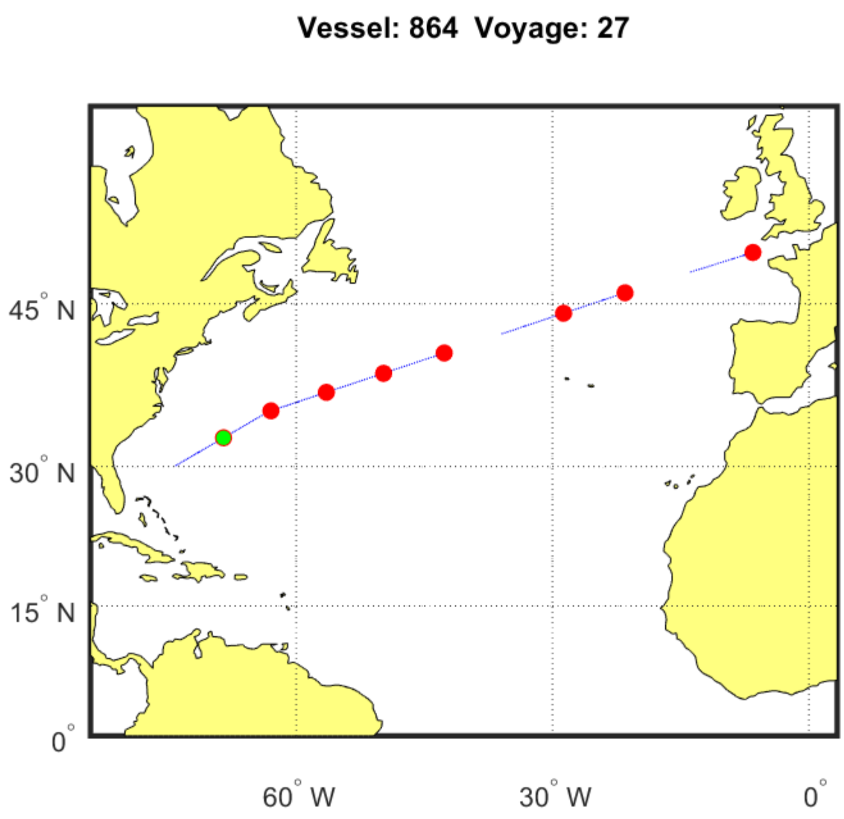
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
11	24	335	336	13.99	586.1	26.36	
12	23	314	316	13.82	616.6	27.39	
13	24	329	326	13.65	630.3	27.77	
14	23	332	309	13.46	640.3	27.86	
15	24	344	335	13.98	592.0	26.94	
17	24	336	328	13.69	633.8	27.89	
18	23	321	311	13.52	663.0	28.81	
20	23	310	310	13.48	634.9	27.57	

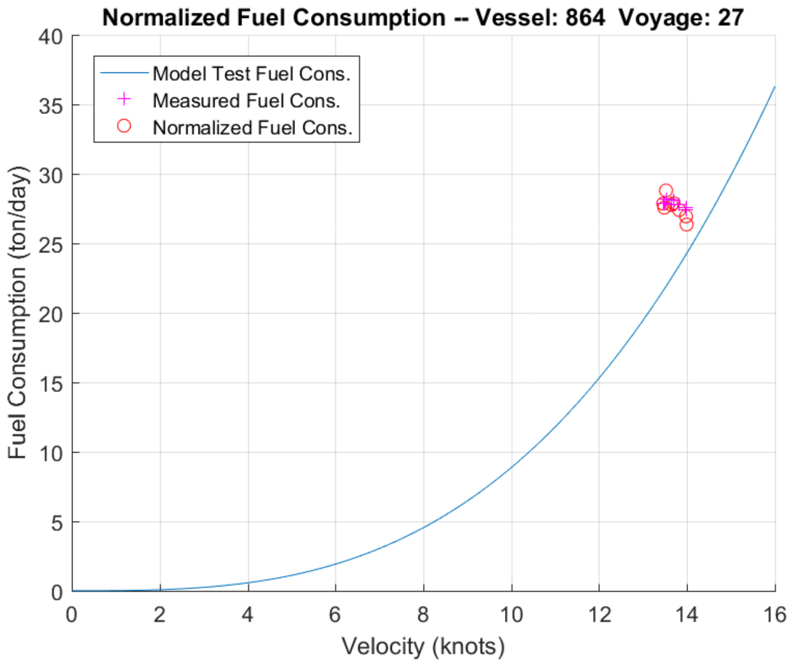
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 8 filtered out due to maneuvering.
Noon Report 9 filtered out due to maneuvering.
Noon Report 10 filtered out due to maneuvering.
Noon Report 21 filtered out due to maneuvering.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.
Noon Report 16 filtered out due to inconsistent AIS/NR lengths.
Noon Report 19 filtered out due to inconsistent AIS/NR lengths.

e **Voyage Map:**



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 28

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
8	24-Aug-2016 13:00:00	25-Aug-2016 14:00:00	10.40	28.90 40.43	0.00 42.20	0.00 42.43
9	25-Aug-2016 14:00:00	26-Aug-2016 14:00:00	10.40	26.80 40.43	0.00 42.20	0.00 42.43
10	26-Aug-2016 14:00:00	27-Aug-2016 15:00:00	10.40	28.20 40.43	0.00 42.20	0.00 42.43
11	27-Aug-2016 15:00:00	28-Aug-2016 15:00:00	10.40	25.80 40.43	0.00 42.20	0.00 42.43
12	28-Aug-2016 15:00:00	29-Aug-2016 15:00:00	10.40	25.80 40.43	0.00 42.20	0.00 42.43
13	29-Aug-2016 15:00:00	30-Aug-2016 16:00:00	10.40	27.80 40.43	0.00 42.20	0.00 42.43

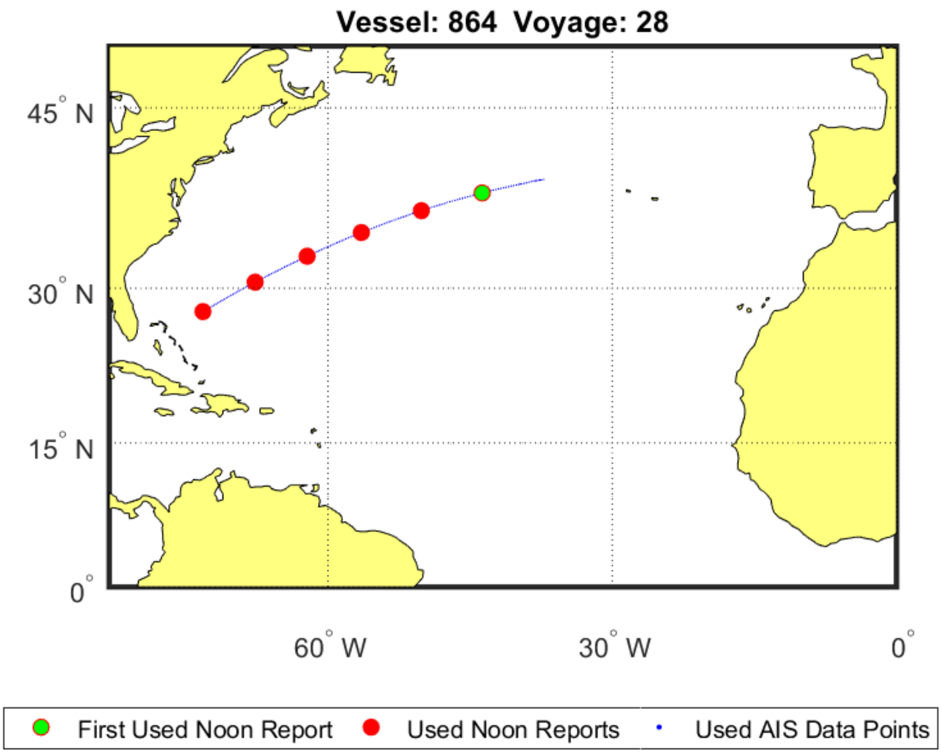
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
8	25	316	316	12.69	644.0	26.27	
9	24	317	313	13.09	591.8	24.99	
10	25	326	319	12.79	650.8	26.78	
11	24	310	308	12.86	625.8	25.86	
12	24	311	311	13.01	624.0	26.08	
13	25	330	331	13.25	628.7	26.77	

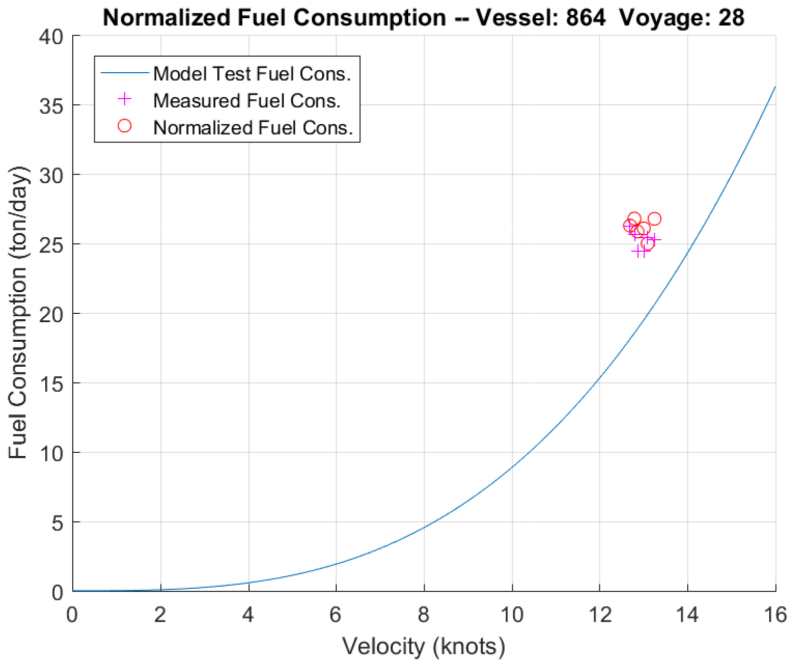
Filtered Data:

Noon Report 7 filtered out due to acceleration.
Noon Report 18 filtered out due to acceleration.
Noon Report 1 filtered out due to maneuvering.
Noon Report 2 filtered out due to maneuvering.
Noon Report 3 filtered out due to maneuvering.
Noon Report 5 filtered out due to maneuvering.
Noon Report 6 filtered out due to maneuvering.
Noon Report 14 filtered out due to maneuvering.
Noon Report 15 filtered out due to maneuvering.
Noon Report 16 filtered out due to maneuvering.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 17 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 29

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
10	22-Sep-2016 17:00:00	23-Sep-2016 17:00:00	11.70	33.20 40.43	0.00 42.20	0.20 42.43

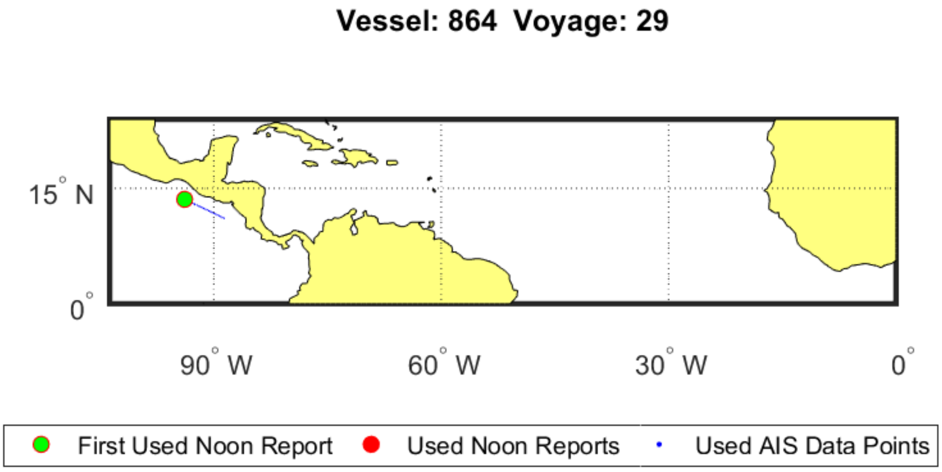
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
10	24	344	346	14.46	676.2	31.47	

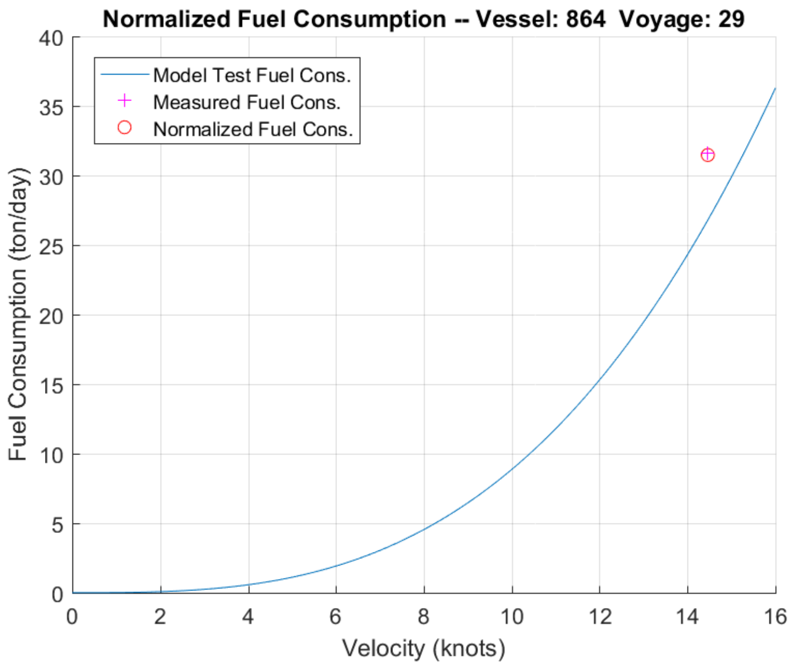
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 11 filtered out due to acceleration.
Noon Report 2 filtered out due to maneuvering.
Noon Report 4 filtered out due to maneuvering.
Noon Report 5 filtered out due to maneuvering.
Noon Report 6 filtered out due to maneuvering.
Noon Report 7 filtered out due to maneuvering.
Noon Report 8 filtered out due to maneuvering.
Noon Report 9 filtered out due to maneuvering.
Noon Report 12 filtered out due to maneuvering.
Noon Report 13 filtered out due to maneuvering.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 7 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 1601

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
10	30-Nov-2016 19:00:00	01-Dec-2016 19:00:00	11.80	25.00 40.43	0.00 42.20	0.00 42.43
13	03-Dec-2016 18:00:00	04-Dec-2016 18:00:00	11.80	28.50 40.43	0.00 42.20	0.00 42.43
15	05-Dec-2016 17:00:00	06-Dec-2016 17:00:00	11.80	29.70 40.43	0.00 42.20	0.00 42.43
16	06-Dec-2016 17:00:00	07-Dec-2016 17:00:00	11.80	29.30 40.43	0.00 42.20	0.00 42.43
18	08-Dec-2016 16:00:00	09-Dec-2016 16:00:00	11.80	28.50 40.43	0.00 42.20	0.00 42.43
21	11-Dec-2016 16:00:00	12-Dec-2016 15:00:00	11.80	26.90 40.43	0.00 42.20	0.00 42.43

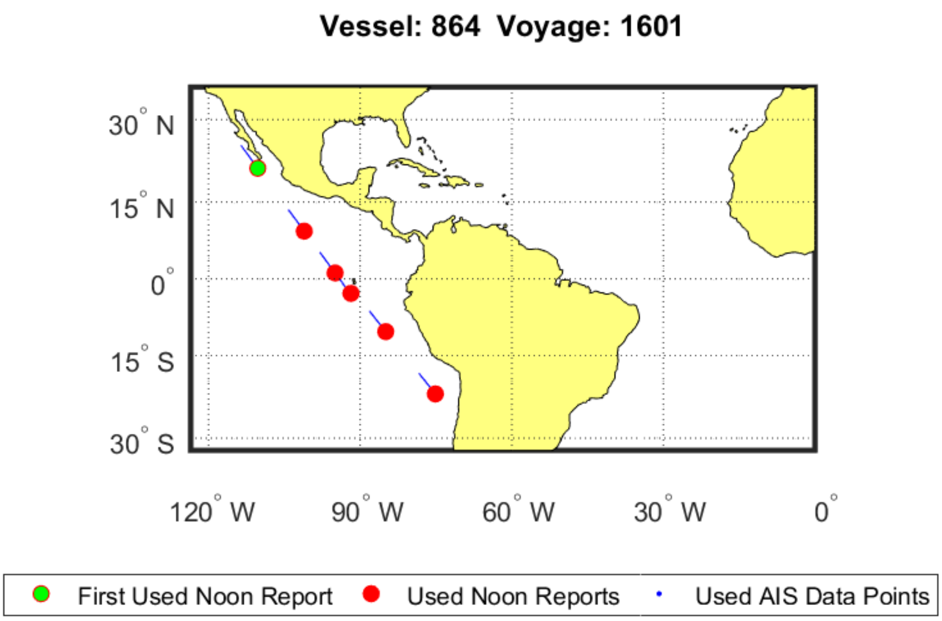
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
10	24	307	307	12.81	568.1	23.39	
13	24	310	316	13.19	619.7	26.25	
15	24	302	306	12.76	657.6	26.96	
16	24	313	322	13.45	615.7	26.72	
18	24	305	308	12.86	624.5	25.79	
21	23	292	297	12.91	602.9	24.99	

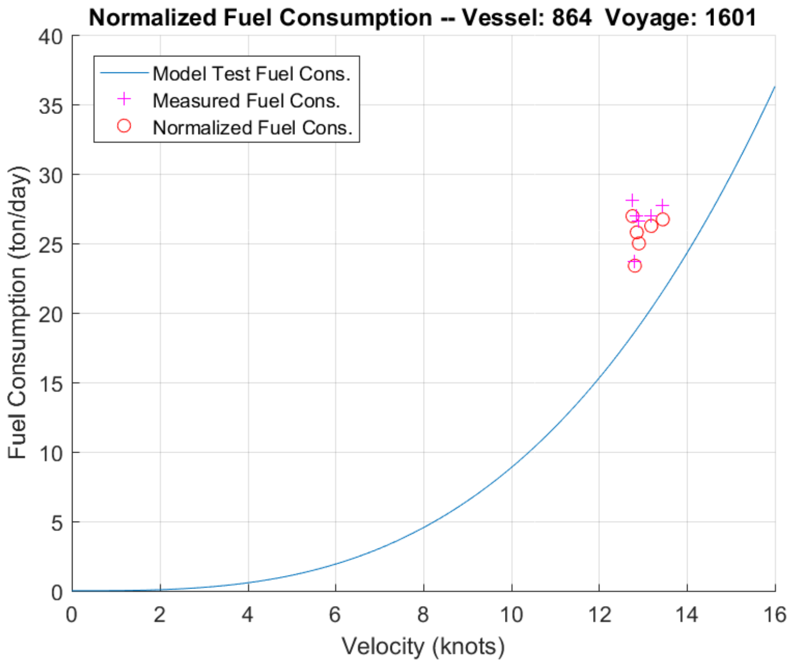
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 7 filtered out due to acceleration.
Noon Report 12 filtered out due to acceleration.
Noon Report 19 filtered out due to acceleration.
Noon Report 6 filtered out due to maneuvering.
Noon Report 22 filtered out due to maneuvering.
Noon Report 23 filtered out due to maneuvering.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.
Noon Report 17 filtered out due to inconsistent AIS/NR lengths.
Noon Report 20 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 22

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
20	17-Nov-2015 18:00:00	18-Nov-2015 18:00:00	11.70	24.80 40.30	0.00 42.20	0.00 42.20
21	18-Nov-2015 18:00:00	19-Nov-2015 18:00:00	11.70	24.50 40.30	0.00 42.20	0.00 42.20
22	19-Nov-2015 19:00:00	20-Nov-2015 19:00:00	11.70	24.50 40.30	0.00 42.20	0.00 42.20
23	20-Nov-2015 19:00:00	21-Nov-2015 20:00:00	11.05	24.80 40.30	0.00 42.20	0.00 42.20

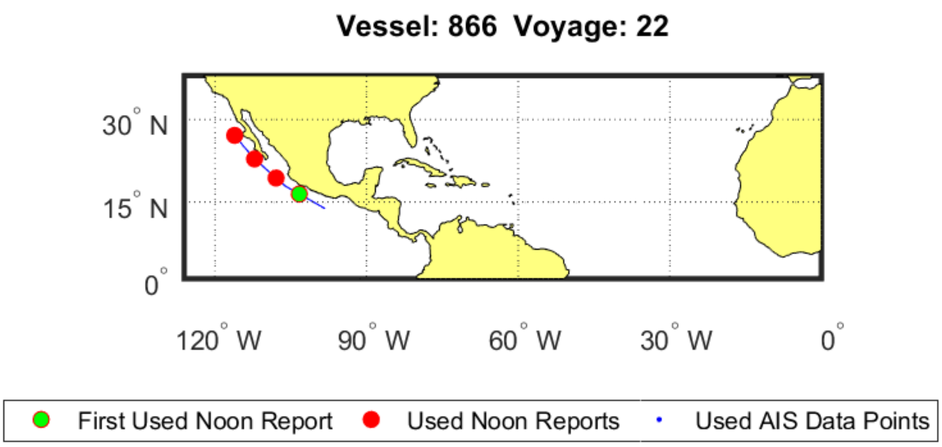
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
20	24	336	331	13.83	516.4	22.96	
21	24	307	304	12.79	517.8	21.34	
22	24	315	314	13.21	490.7	20.82	
23	25	329	330	13.21	486.6	20.66	

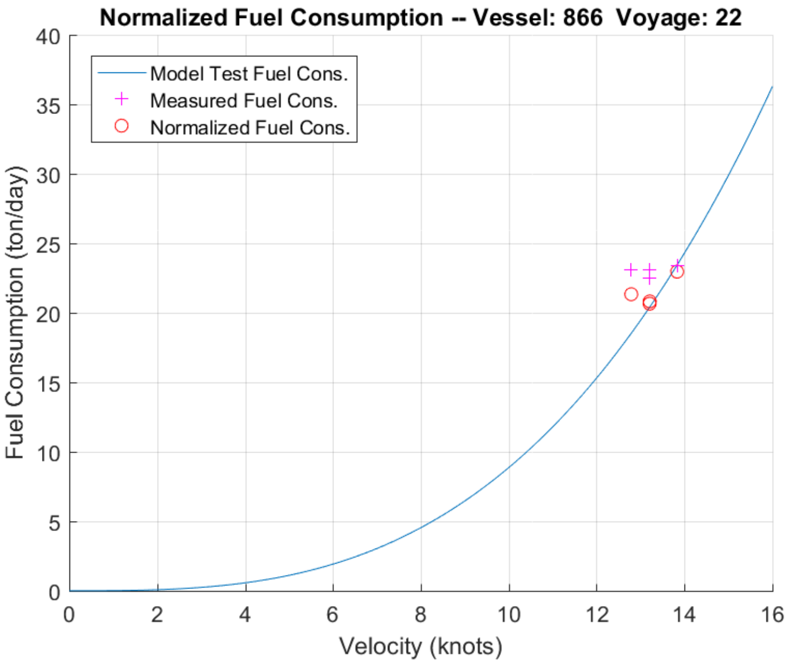
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to acceleration.
Noon Report 12 filtered out due to maneuvering.
Noon Report 14 filtered out due to maneuvering.
Noon Report 15 filtered out due to maneuvering.
Noon Report 16 filtered out due to maneuvering.
Noon Report 17 filtered out due to maneuvering.
Noon Report 24 filtered out due to maneuvering.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 5 filtered out due to inconsistent AIS/NR lengths.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 10 filtered out due to inconsistent AIS/NR lengths.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 18 filtered out due to inconsistent AIS/NR lengths.
Noon Report 19 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to lack of AIS data.
Noon Report 6 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 24

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
5	07-Jan-2016 20:00:00	08-Jan-2016 20:00:00	10.40	0.00 40.30	0.00 42.20	25.50 42.20
8	10-Jan-2016 19:00:00	11-Jan-2016 19:00:00	10.20	25.20 40.30	0.00 42.20	0.00 42.20
9	11-Jan-2016 19:00:00	12-Jan-2016 18:00:00	10.20	24.50 40.30	0.00 42.20	0.00 42.20

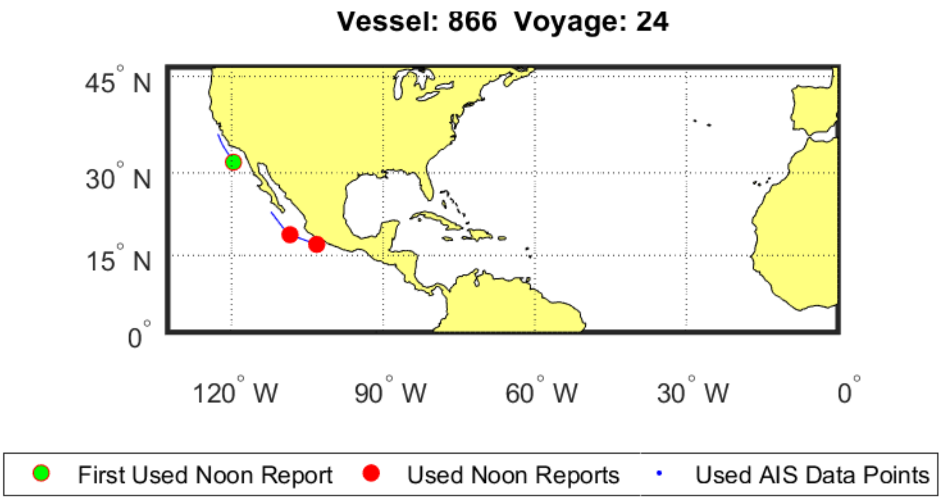
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
5	24	319	320	13.38	639.4	27.52	
8	24	335	338	14.14	569.3	25.86	
9	23	320	319	13.88	583.9	26.03	

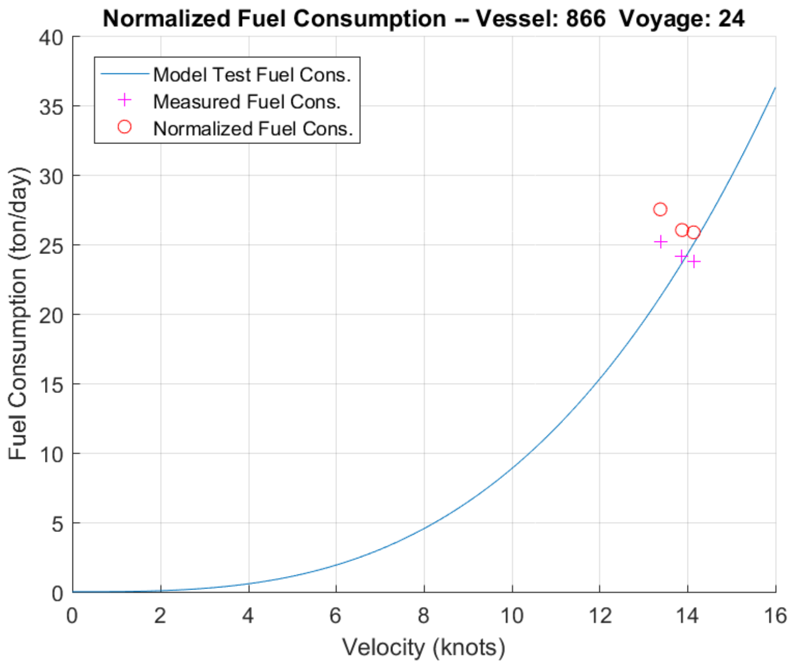
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to maneuvering.
Noon Report 7 filtered out due to maneuvering.
Noon Report 11 filtered out due to maneuvering.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 10 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 34

Vessel Type: MR

Filters:
Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

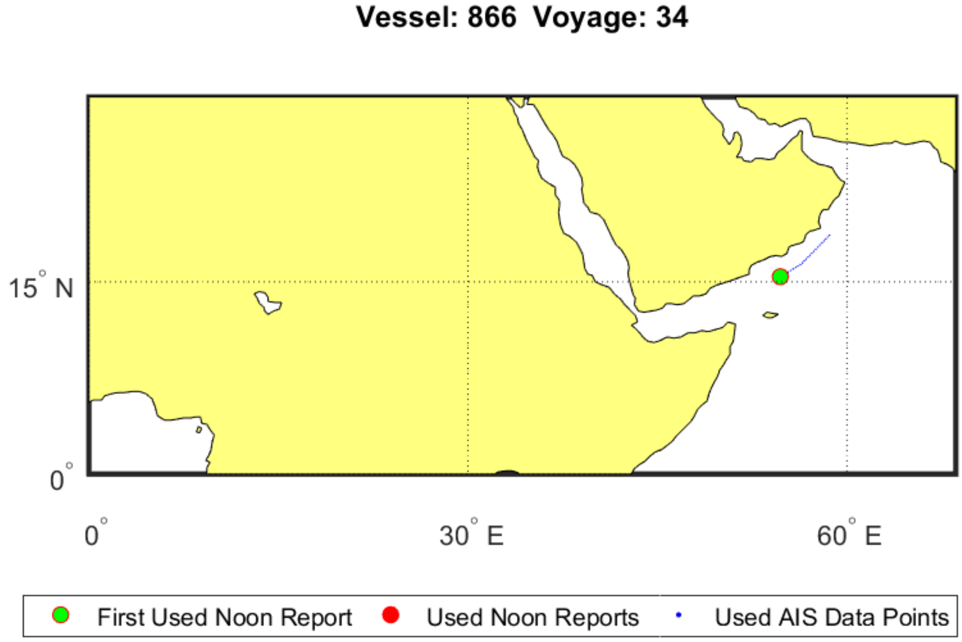
NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
8	05-Oct-2016 08:00:00	06-Oct-2016 08:00:00	10.65	26.20 40.20	0.00 42.20	0.00 42.30

AIS Calculated Data:

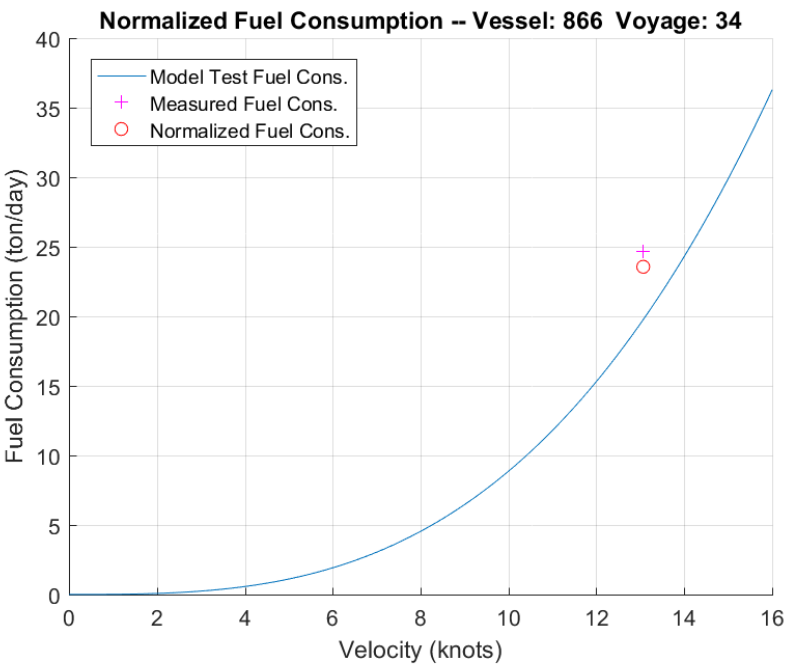
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
8	24	302	313	13.07	559.9	23.56	

Filtered Data:
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 5 filtered out due to acceleration.
Noon Report 3 filtered out due to maneuvering.
Noon Report 4 filtered out due to maneuvering.
Noon Report 7 filtered out due to maneuvering.
Noon Report 9 filtered out due to maneuvering.
Noon Report 10 filtered out due to maneuvering.
Noon Report 11 filtered out due to maneuvering.
Noon Report 12 filtered out due to maneuvering.
Noon Report 13 filtered out due to maneuvering.
Noon Report 14 filtered out due to maneuvering.
Noon Report 15 filtered out due to maneuvering.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 36

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
10	19-Nov-2016 09:00:00	20-Nov-2016 09:00:00	10.70	27.60 40.20	0.00 42.20	0.00 42.30
15	24-Nov-2016 09:00:00	25-Nov-2016 09:00:00	10.70	28.50 40.20	0.00 42.20	0.00 42.30
17	26-Nov-2016 09:00:00	26-Nov-2016 16:00:00	10.70	8.30 40.20	0.00 42.20	0.00 42.30

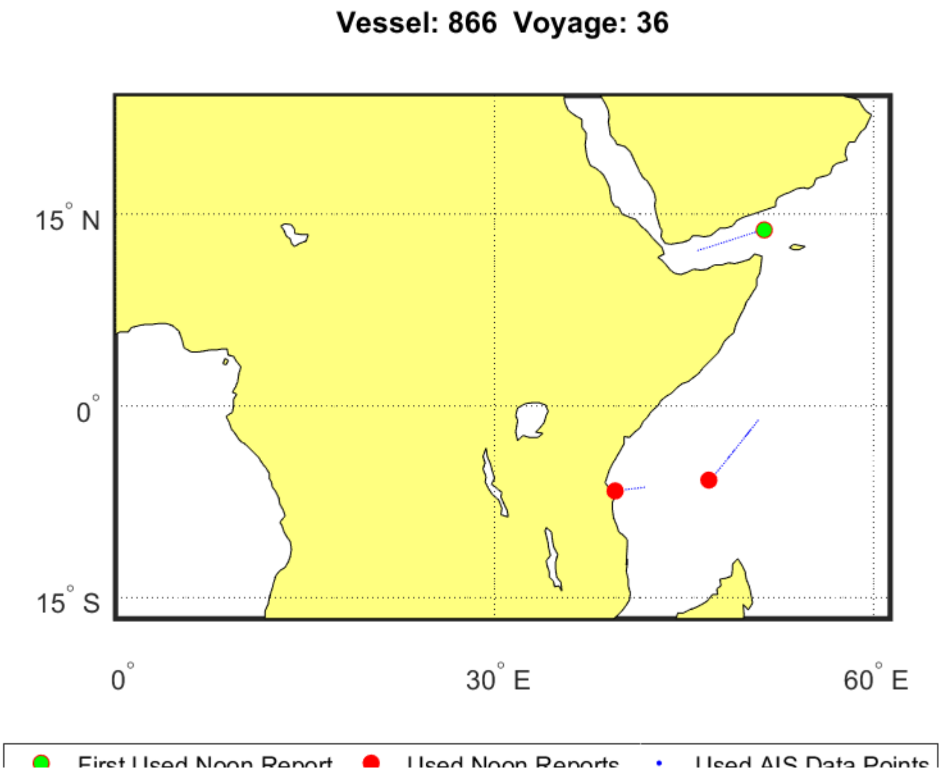
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
10	24	332	344	14.35	569.9	26.29	
15	24	326	324	13.61	638.7	27.96	
17	7	101	102	14.54	607.9	28.38	

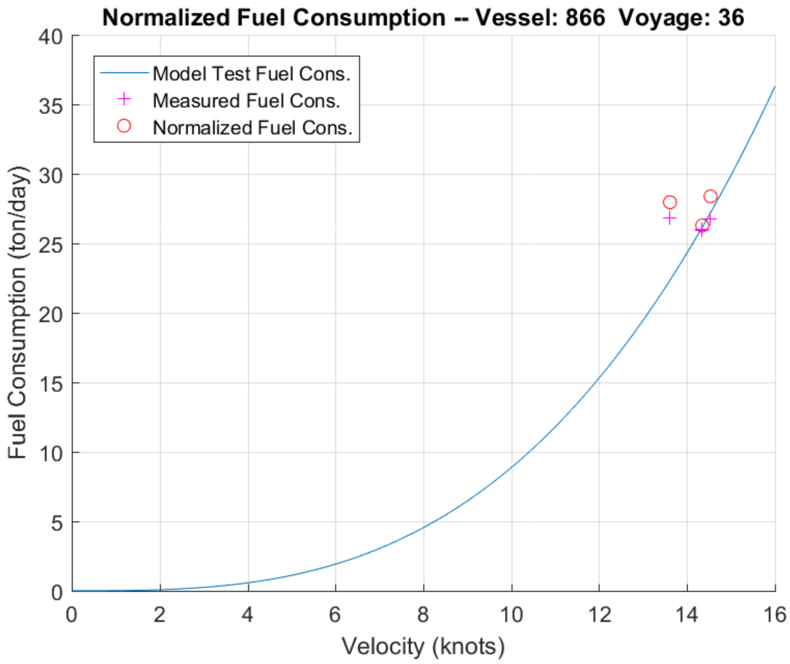
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to maneuvering.
Noon Report 7 filtered out due to maneuvering.
Noon Report 8 filtered out due to maneuvering.
Noon Report 11 filtered out due to maneuvering.
Noon Report 12 filtered out due to maneuvering.
Noon Report 13 filtered out due to maneuvering.
Noon Report 14 filtered out due to maneuvering.
Noon Report 16 filtered out due to maneuvering.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



2 Model 1 Voyage Reports - Static Filters

This section includes the voyage reports from Model 1 using only the static filters. When running these models in MATLAB, the maximum standard deviation of both the speed and heading were set to 10, which is sufficiently large to ensure that none of the noon reports will be removed.

Results which are marked with "Missing Wave Info" indicates that the hindcast data set used for wave details did not include data for the specific location analyzed. Results which are shown as "NaN" indicates that the hindcast data set used for ocean currents did not include data for the specific location analyzed. In both cases, these data points are not used in the overall performance analysis performed as part of this thesis.

3 Model 2 Output

Vessel: 885; Voyage Name: 4025001

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
3	26-Oct-2015 09:00:00	27-Oct-2015 09:00:00	21.00	59.90 40.30	0.00 42.20	0.00 42.20
4	27-Oct-2015 09:00:00	28-Oct-2015 09:00:00	21.00	64.70 40.30	0.00 42.20	0.00 42.20
5	28-Oct-2015 09:00:00	29-Oct-2015 09:00:00	21.00	61.20 40.30	0.00 42.20	0.00 42.20
8	05-Nov-2015 11:00:00	06-Nov-2015 10:00:00	20.85	68.10 40.30	0.00 42.20	0.00 42.20
10	07-Nov-2015 11:00:00	08-Nov-2015 11:00:00	20.85	69.70 40.30	0.00 42.20	0.00 42.20
14	11-Nov-2015 11:00:00	12-Nov-2015 12:00:00	20.85	85.30 40.30	0.00 42.20	0.00 42.20
18	15-Nov-2015 13:00:00	16-Nov-2015 14:00:00	20.85	85.10 40.30	0.00 42.20	0.00 42.20
19	16-Nov-2015 14:00:00	17-Nov-2015 14:00:00	20.85	82.30 40.30	0.00 42.20	0.00 42.20
21	18-Nov-2015 15:00:00	19-Nov-2015 15:00:00	20.85	81.70 40.30	0.00 42.20	0.00 42.20
25	22-Nov-2015 17:00:00	23-Nov-2015 17:00:00	20.85	71.60 40.30	0.00 42.20	0.00 42.20

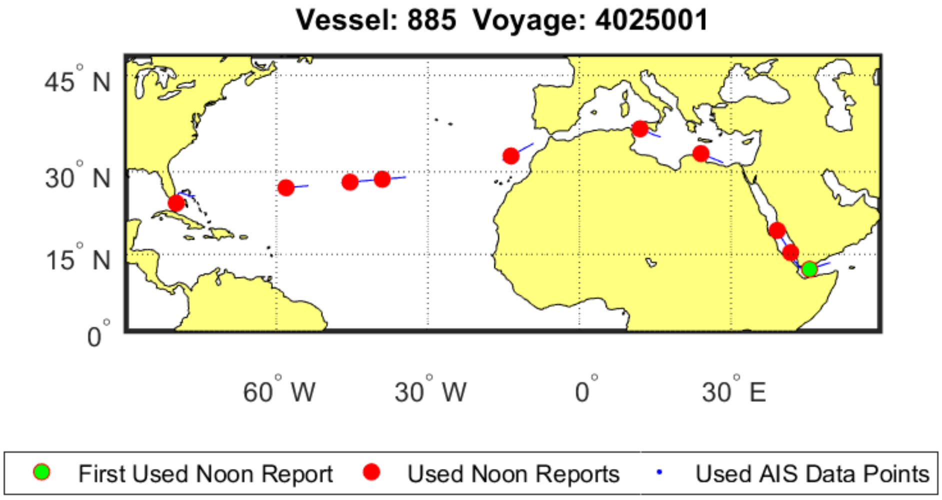
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
3	24	314	299	12.46	1629.1	57.68	
4	24	325	312	13.00	1728.7	64.10	**
5	24	297	294	12.24	1663.8	60.33	**
8	23	306	303	13.21	1787.0	66.84	**
10	24	306	308	12.90	1770.2	67.92	**
14	25	351	351	14.03	1960.5	77.94	
18	25	342	342	13.96	1928.5	76.23	
19	24	332	330	13.76	2016.9	78.65	
21	24	328	325	13.55	2040.5	78.36	
25	24	301	315	13.14	1828.1	68.22	

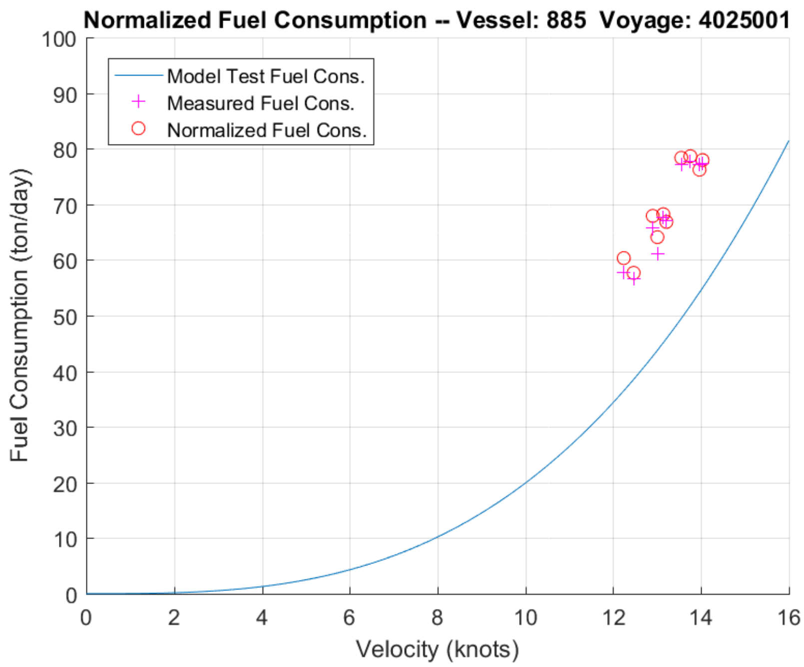
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.
Noon Report 12 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 15 filtered out due to inconsistent AIS/NR lengths.
Noon Report 16 filtered out due to inconsistent AIS/NR lengths.
Noon Report 17 filtered out due to inconsistent AIS/NR lengths.
Noon Report 20 filtered out due to inconsistent AIS/NR lengths.
Noon Report 22 filtered out due to inconsistent AIS/NR lengths.
Noon Report 23 filtered out due to inconsistent AIS/NR lengths.
Noon Report 24 filtered out due to inconsistent AIS/NR lengths.
Noon Report 26 filtered out due to inconsistent AIS/NR lengths.
Noon Report 27 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 885; Voyage Name: 4025002

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
20	18-Jan-2016 08:00:00	19-Jan-2016 07:00:00	21.65	69.50 40.30	0.00 42.20	0.00 42.20
21	19-Jan-2016 07:00:00	20-Jan-2016 07:00:00	21.65	71.90 40.30	0.00 42.20	0.00 42.20
22	20-Jan-2016 07:00:00	21-Jan-2016 07:00:00	21.65	72.00 40.30	0.00 42.20	0.00 42.20

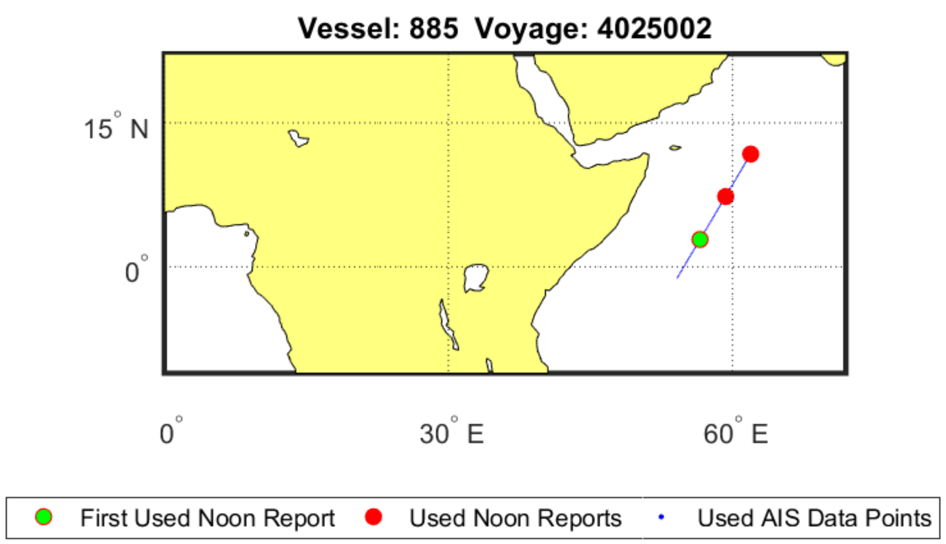
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
20	23	299	319	13.88	1660.5	65.35	
21	24	314	308	12.83	1776.7	64.52	
22	24	306	310	12.91	1709.2	62.50	

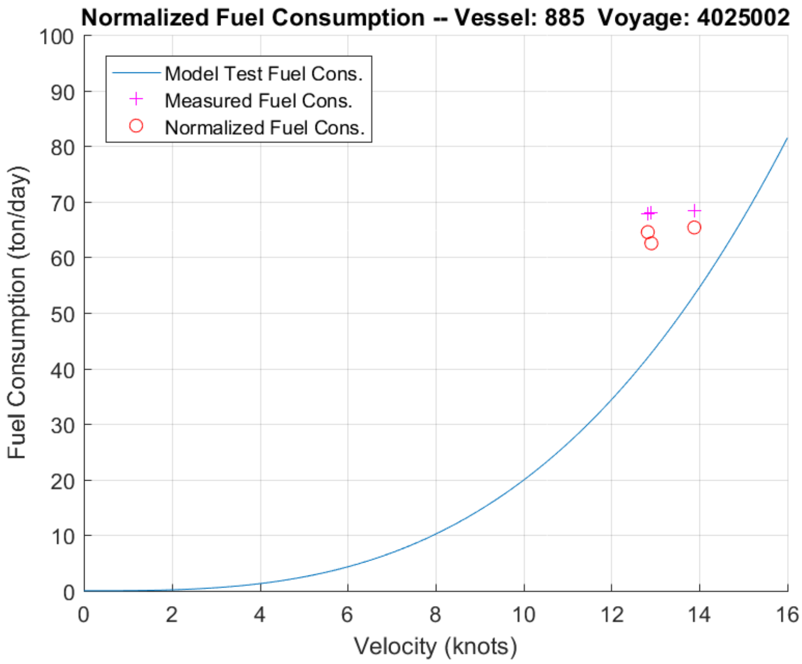
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 18 filtered out due to inconsistent AIS/NR lengths.
Noon Report 19 filtered out due to inconsistent AIS/NR lengths.
Noon Report 23 filtered out due to inconsistent AIS/NR lengths.
Noon Report 24 filtered out due to inconsistent AIS/NR lengths.
Noon Report 25 filtered out due to inconsistent AIS/NR lengths.
Noon Report 5 filtered out due to lack of AIS data.
Noon Report 6 filtered out due to lack of AIS data.
Noon Report 7 filtered out due to lack of AIS data.
Noon Report 8 filtered out due to lack of AIS data.
Noon Report 9 filtered out due to lack of AIS data.
Noon Report 10 filtered out due to lack of AIS data.
Noon Report 11 filtered out due to lack of AIS data.
Noon Report 12 filtered out due to lack of AIS data.
Noon Report 13 filtered out due to lack of AIS data.
Noon Report 14 filtered out due to lack of AIS data.
Noon Report 15 filtered out due to lack of AIS data.
Noon Report 16 filtered out due to lack of AIS data.
Noon Report 17 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 885; Voyage Name: 4025003

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
6	08-Feb-2016 20:00:00	09-Feb-2016 09:00:00	20.25	36.62 40.30	0.00 42.20	0.00 42.20
7	09-Feb-2016 09:00:00	10-Feb-2016 09:00:00	20.25	65.66 40.30	0.00 42.20	0.00 42.20
8	10-Feb-2016 09:00:00	11-Feb-2016 08:00:00	20.25	68.42 40.30	0.00 42.20	0.00 42.20
9	11-Feb-2016 08:00:00	12-Feb-2016 08:00:00	20.25	63.28 40.30	0.00 42.20	0.00 42.20
10	12-Feb-2016 08:00:00	13-Feb-2016 08:00:00	20.25	60.81 40.30	0.00 42.20	0.00 42.20
11	13-Feb-2016 08:00:00	14-Feb-2016 06:00:00	20.25	57.14 40.30	0.00 42.20	0.00 42.20

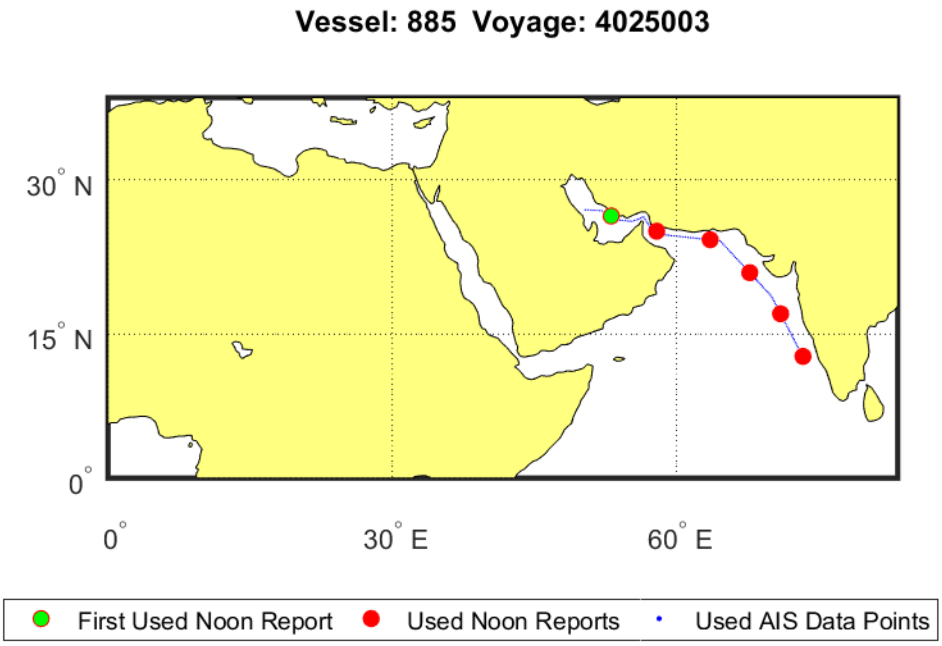
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
6	13	176	176	13.56	1726.1	66.32	
7	24	318	318	13.27	1694.1	64.03	
8	23	314	319	13.86	1776.6	69.72	
9	24	311	314	13.07	1678.6	62.24	
10	24	311	312	13.00	1600.6	58.96	
11	22	286	285	12.97	1678.8	61.65	

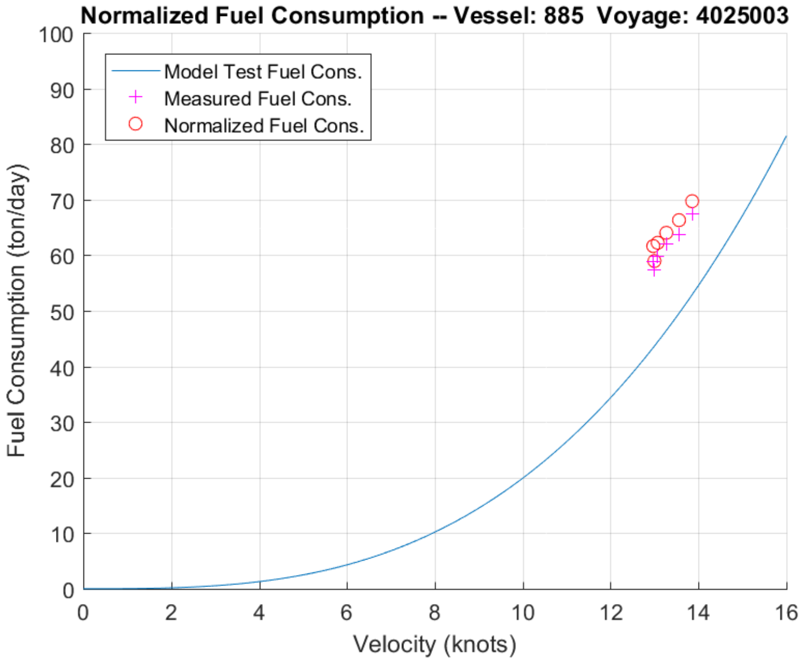
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 12 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.
Noon Report 15 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 885; Voyage Name: 4025004

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
14	10-Mar-2016 09:00:00	11-Mar-2016 09:00:00	20.73	76.20 40.30	0.00 42.20	0.00 42.20
15	11-Mar-2016 09:00:00	12-Mar-2016 08:00:00	20.62	77.30 40.30	0.00 42.20	0.00 42.20
16	12-Mar-2016 08:00:00	13-Mar-2016 08:00:00	20.68	74.20 40.30	0.00 42.20	0.00 42.20
17	13-Mar-2016 08:00:00	14-Mar-2016 08:00:00	20.68	75.30 40.30	0.00 42.20	0.00 42.20
18	14-Mar-2016 08:00:00	15-Mar-2016 07:00:00	20.68	81.00 40.30	0.00 42.20	0.00 42.20
19	15-Mar-2016 07:00:00	16-Mar-2016 07:00:00	20.68	84.20 40.30	0.00 42.20	0.00 42.20
20	16-Mar-2016 07:00:00	17-Mar-2016 06:00:00	20.68	82.20 40.30	0.00 42.20	0.00 42.20
21	17-Mar-2016 06:00:00	18-Mar-2016 06:00:00	20.68	86.00 40.30	0.00 42.20	0.00 42.20
22	18-Mar-2016 06:00:00	19-Mar-2016 05:00:00	20.68	87.10 40.30	0.00 42.20	0.00 42.20
23	19-Mar-2016 05:00:00	20-Mar-2016 05:00:00	20.68	92.80 40.30	0.00 42.20	0.00 42.20
24	20-Mar-2016 05:00:00	21-Mar-2016 04:00:00	20.68	67.40 40.30	0.00 42.20	0.00 42.20
25	21-Mar-2016 04:00:00	22-Mar-2016 04:00:00	20.68	21.10 40.30	0.00 42.20	0.00 42.20
26	22-Mar-2016 04:00:00	23-Mar-2016 04:00:00	20.50	77.10 40.30	0.00 42.20	0.00 42.20
27	23-Mar-2016 04:00:00	24-Mar-2016 04:00:00	20.50	83.60 40.30	0.00 42.20	0.00 42.20
28	24-Mar-2016 04:00:00	25-Mar-2016 04:00:00	20.50	82.30 40.30	0.00 42.20	0.00 42.20
29	25-Mar-2016 04:00:00	26-Mar-2016 04:00:00	20.50	87.70 40.30	0.00 42.20	0.00 42.20
31	27-Mar-2016 04:00:00	28-Mar-2016 04:00:00	20.50	86.90 40.30	0.00 42.20	0.00 42.20
32	28-Mar-2016 04:00:00	29-Mar-2016 04:00:00	20.50	78.20 40.30	0.00 42.20	0.00 42.20

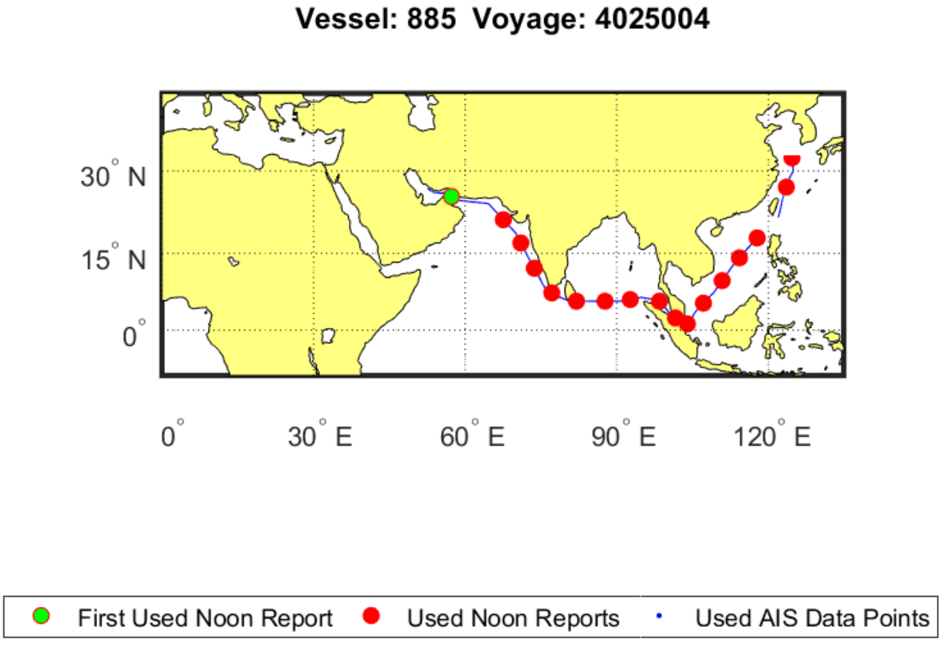
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
14	24	327	329	13.70	1840.1	74.24	
15	23	323	329	14.29	1923.7	77.81	
16	24	329	330	13.75	1852.0	72.11	
17	24	330	335	13.97	1836.7	72.72	
18	23	330	331	14.37	1990.9	84.57	
19	24	361	349	14.54	1958.1	80.68	
20	23	315	320	13.91	2002.8	86.58	**
21	24	338	357	14.87	1965.2	82.75	
22	23	300	329	14.30	2147.7	86.99	
23	24	354	353	14.71	2144.4	89.37	
24	23	272	271	11.78	1890.6	73.02	
25	24	174	NaN	NaN	NaN	NaN	**
26	24	329	337	14.04	1868.2	74.24	**
27	24	346	334	13.92	2039.4	80.39	
28	24	331	336	14.02	1989.1	78.92	
29	24	304	315	13.13	1960.6	73.15	
31	24	354	335	13.96	2013.8	79.78	
32	24	334	333	13.88	1873.1	73.78	

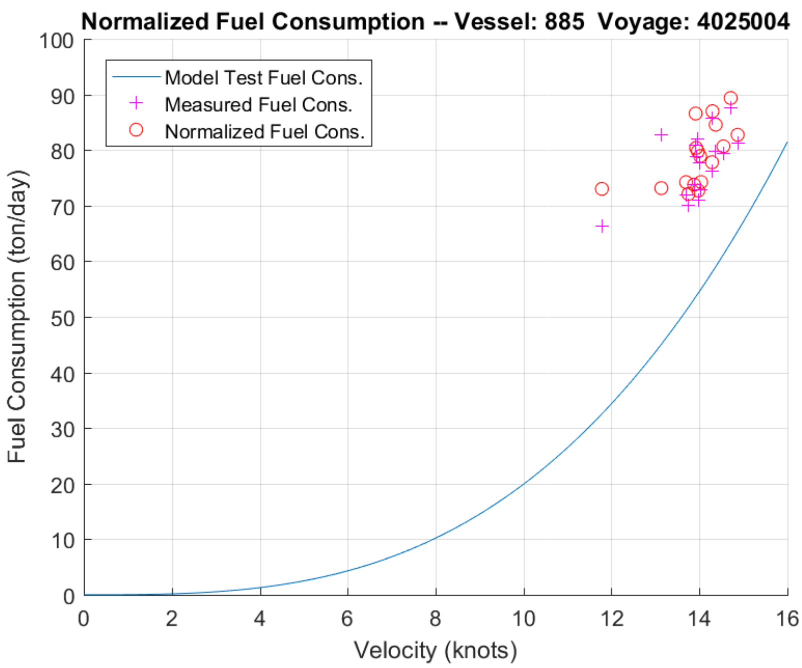
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 34 filtered out due to draft.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 30 filtered out due to inconsistent AIS/NR lengths.
Noon Report 33 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 885; Voyage Name: 4025005

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
26	20-May-2016 09:00:00	21-May-2016 09:00:00	20.50	70.90 40.30	0.00 42.20	0.00 42.20
27	21-May-2016 09:00:00	22-May-2016 08:00:00	20.50	68.00 40.30	0.00 42.20	0.00 42.20
28	22-May-2016 08:00:00	23-May-2016 08:00:00	20.50	67.90 40.30	0.00 42.20	0.00 42.20
29	23-May-2016 08:00:00	24-May-2016 07:00:00	20.40	65.70 40.30	0.00 42.20	0.00 42.20
30	24-May-2016 07:00:00	25-May-2016 07:00:00	20.40	72.60 40.30	0.00 42.20	0.00 42.20
31	25-May-2016 07:00:00	26-May-2016 07:00:00	20.40	76.30 40.30	0.00 42.20	0.00 42.20
32	26-May-2016 07:00:00	27-May-2016 06:00:00	20.40	72.50 40.30	0.00 42.20	0.00 42.20
33	27-May-2016 06:00:00	28-May-2016 06:00:00	20.40	65.00 40.30	0.00 42.20	0.00 42.20
34	28-May-2016 06:00:00	29-May-2016 06:00:00	20.40	50.00 40.30	0.00 42.20	0.00 42.20
36	30-May-2016 05:00:00	31-May-2016 05:00:00	20.40	40.00 40.30	0.00 42.20	0.00 42.20
37	31-May-2016 05:00:00	01-Jun-2016 04:00:00	20.40	50.00 40.30	0.00 42.20	0.00 42.20
38	01-Jun-2016 04:00:00	01-Jun-2016 22:00:00	20.40	30.00 40.30	0.00 42.20	0.00 42.20

AIS Calculated Data:

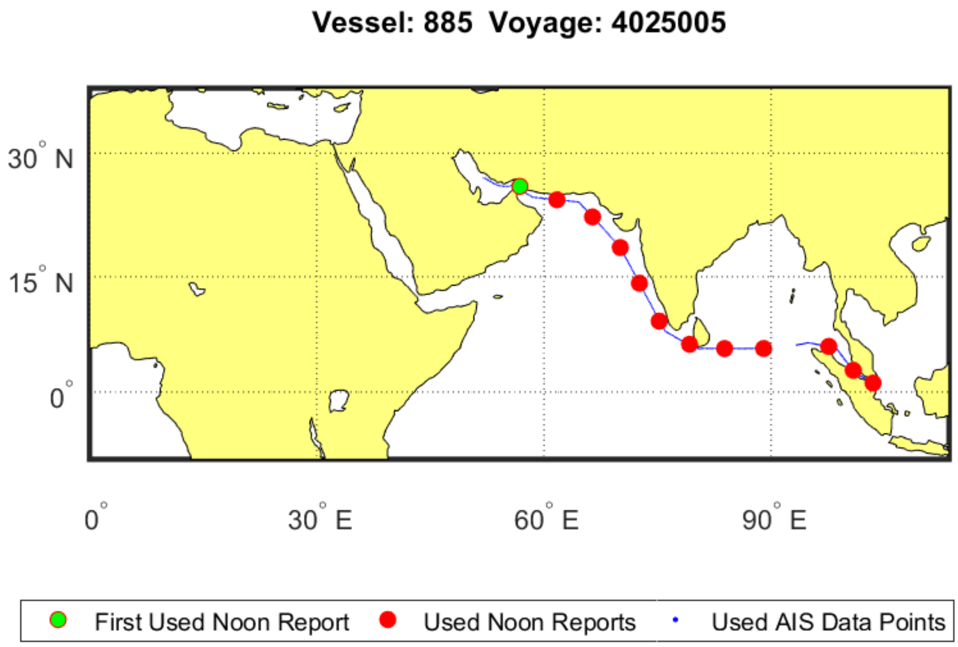
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
26	24	313	313	13.03	1854.1	68.44	
27	23	299	302	13.13	1857.8	69.07	
28	24	306	300	12.52	1848.3	65.58	
29	23	307	300	13.03	1790.3	66.14	
30	24	307	302	12.58	1917.8	71.32	
31	24	331	320	13.33	1948.7	74.52	
32	23	308	301	13.10	2010.7	74.66	
33	24	289	290	12.09	1812.7	68.60	**
34	24	306	287	11.96	1519.2	52.13	
36	24	276	263	10.97	1274.4	40.49	
37	23	275	273	11.88	1471.8	51.27	
38	18	187	NaN	NaN	NaN	NaN	**

Filtered Data:

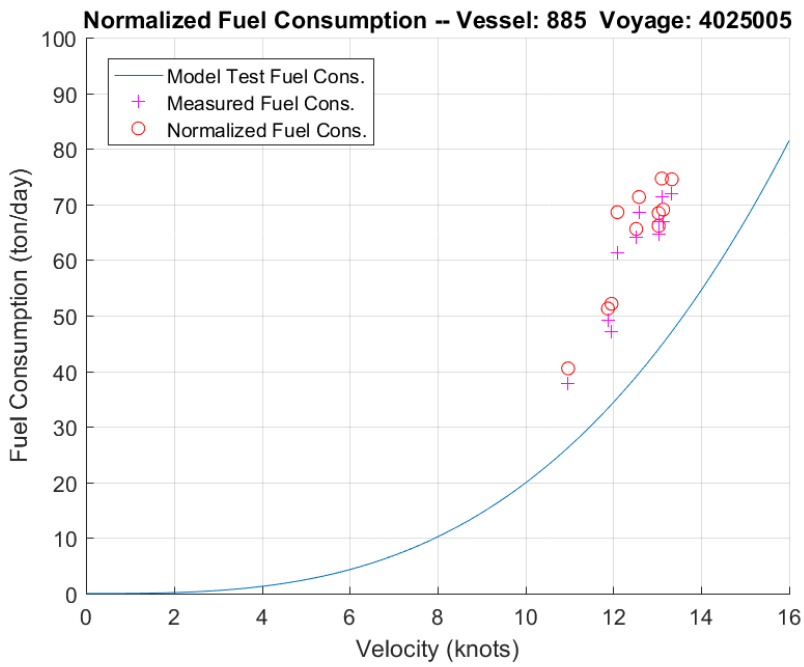
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 20 filtered out due to draft.
Noon Report 21 filtered out due to draft.
Noon Report 22 filtered out due to draft.
Noon Report 23 filtered out due to draft.
Noon Report 24 filtered out due to draft.
Noon Report 25 filtered out due to inconsistent AIS/NR lengths.

Noon Report 35 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 885; Voyage Name: 4025006

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
12	18-Jun-2016 10:00:00	19-Jun-2016 08:00:00	20.40	68.00 40.50	0.00 42.20	0.00 42.20
13	19-Jun-2016 08:00:00	20-Jun-2016 08:00:00	20.40	70.00 40.50	0.00 42.20	0.00 42.20
14	20-Jun-2016 08:00:00	21-Jun-2016 07:00:00	20.40	75.00 40.50	0.00 42.20	0.00 42.20
15	21-Jun-2016 07:00:00	22-Jun-2016 07:00:00	20.40	80.00 40.50	0.00 42.20	0.00 42.20
16	22-Jun-2016 07:00:00	23-Jun-2016 07:00:00	20.40	85.00 40.50	0.00 42.20	0.00 42.20
17	23-Jun-2016 07:00:00	24-Jun-2016 06:00:00	20.40	85.00 40.50	0.00 42.20	0.00 42.20
19	25-Jun-2016 06:00:00	26-Jun-2016 05:00:00	20.40	75.00 40.50	0.00 42.20	0.00 42.20
21	27-Jun-2016 05:00:00	28-Jun-2016 04:00:00	20.40	78.00 40.50	0.00 42.20	0.00 42.20
22	28-Jun-2016 04:00:00	29-Jun-2016	20.40	55.00 40.50	0.00 42.20	0.00 42.20

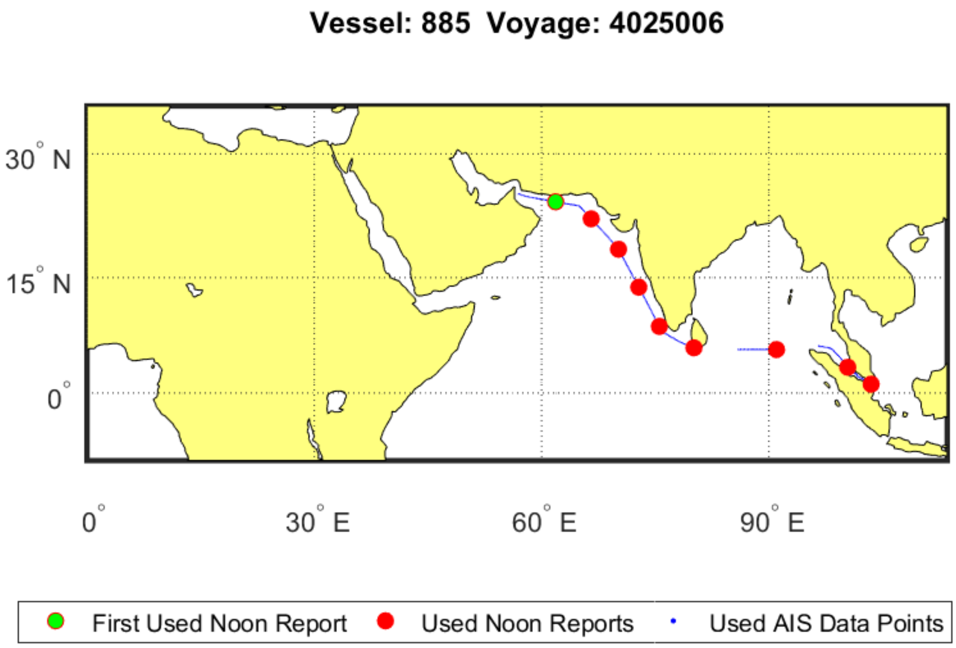
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
12	22	291	292	13.28	1902.4	71.62	
13	24	301	299	12.47	1939.7	68.56	
14	23	305	300	13.04	2078.6	76.71	
15	24	326	322	13.43	2069.3	78.69	
16	24	343	336	13.99	2122.3	84.04	
17	23	316	313	13.62	2291.4	89.15	
19	23	319	293	12.73	2131.2	78.81	
21	23	317	316	13.74	2029.1	79.12	
22	20	227	NaN	NaN	NaN	NaN	**

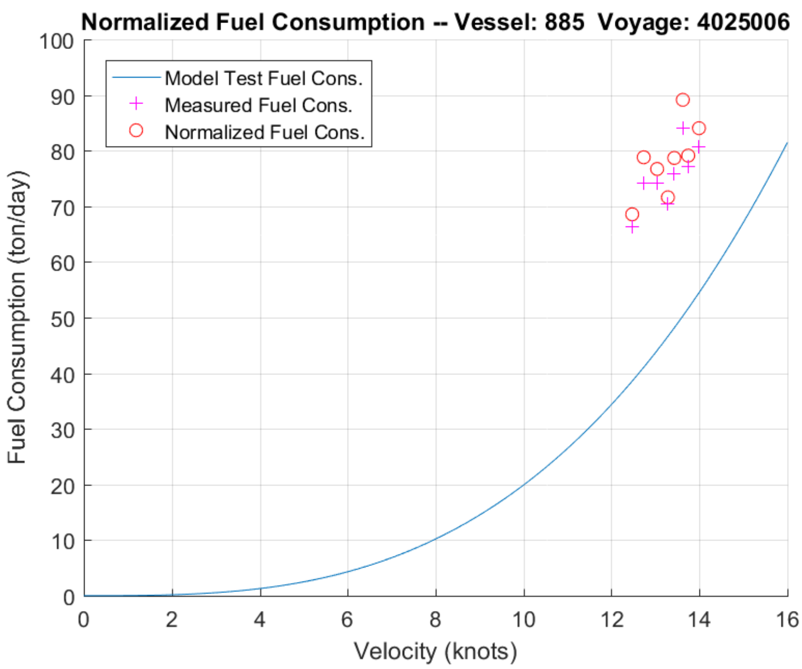
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 18 filtered out due to inconsistent AIS/NR lengths.
Noon Report 20 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 885; Voyage Name: 4025007

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
18	29-Jul-2016 11:00:00	30-Jul-2016 09:00:00	20.80	51.45 40.60	0.00 42.20	0.00 42.20
19	30-Jul-2016 09:00:00	31-Jul-2016 08:00:00	20.80	62.30 40.60	0.00 42.20	0.00 42.20
20	31-Jul-2016 08:00:00	01-Aug-2016 08:00:00	20.80	66.80 40.60	0.00 42.20	0.00 42.20
21	01-Aug-2016 08:00:00	02-Aug-2016 07:00:00	20.80	64.10 40.60	0.00 42.20	0.00 42.20
23	03-Aug-2016 07:00:00	04-Aug-2016 07:00:00	20.80	67.20 40.60	0.00 42.20	0.00 42.20
24	04-Aug-2016 07:00:00	05-Aug-2016 06:00:00	20.80	64.60 40.60	0.00 42.20	0.00 42.20
25	05-Aug-2016 06:00:00	06-Aug-2016 06:00:00	20.80	67.10 40.60	0.00 42.20	0.00 42.20
26	06-Aug-2016 06:00:00	07-Aug-2016 05:00:00	20.80	64.10 40.60	0.00 42.20	0.00 42.20
27	07-Aug-2016 05:00:00	08-Aug-2016 05:00:00	20.80	64.40 40.60	0.00 42.20	0.00 42.20
28	08-Aug-2016 05:00:00	09-Aug-2016 04:00:00	20.80	68.80 40.60	0.00 42.20	0.00 42.20
29	09-Aug-2016 04:00:00	10-Aug-2016 04:00:00	20.80	71.40 40.60	0.00 42.20	0.00 42.20
30	10-Aug-2016 04:00:00	11-Aug-2016 02:00:00	20.80	48.20 40.60	0.00 42.20	0.00 42.20

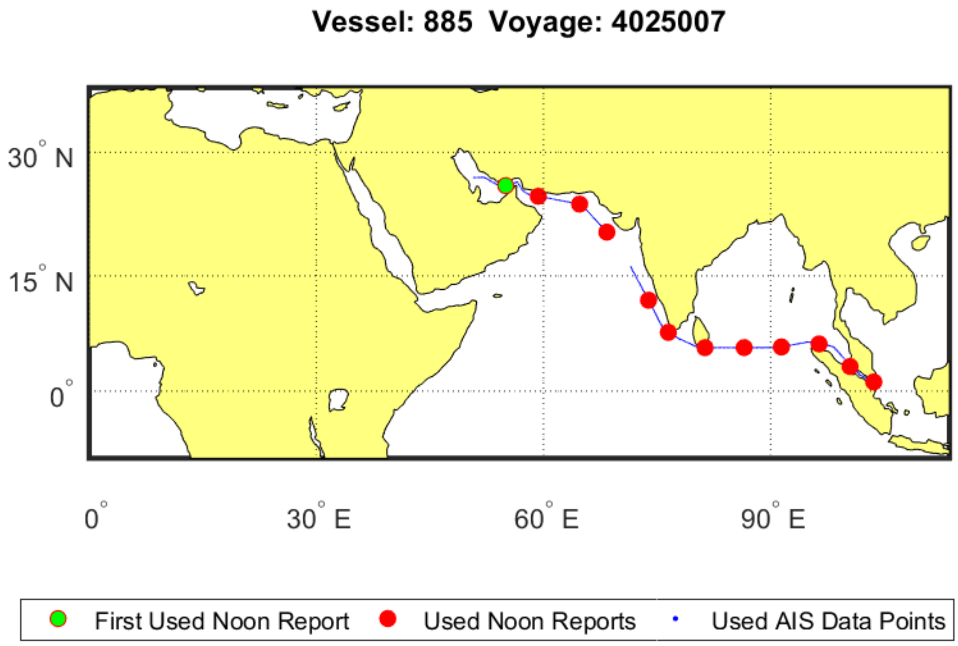
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
18	22	254	256	11.65	1619.1	54.70	
19	23	287	291	12.63	1745.9	62.82	
20	24	305	302	12.60	1805.3	64.44	
21	23	289	283	12.31	1877.3	65.50	
23	24	308	297	12.39	1854.5	65.08	
24	23	298	302	13.14	1787.4	66.52	
25	24	319	312	13.00	1796.1	66.57	
26	23	310	285	12.39	1893.5	66.50	
27	24	296	292	12.18	1805.0	65.42	
28	23	303	301	13.07	1882.1	69.98	
29	24	313	313	13.04	1857.5	69.66	
30	22	230	230	10.44	1643.2	53.33	**

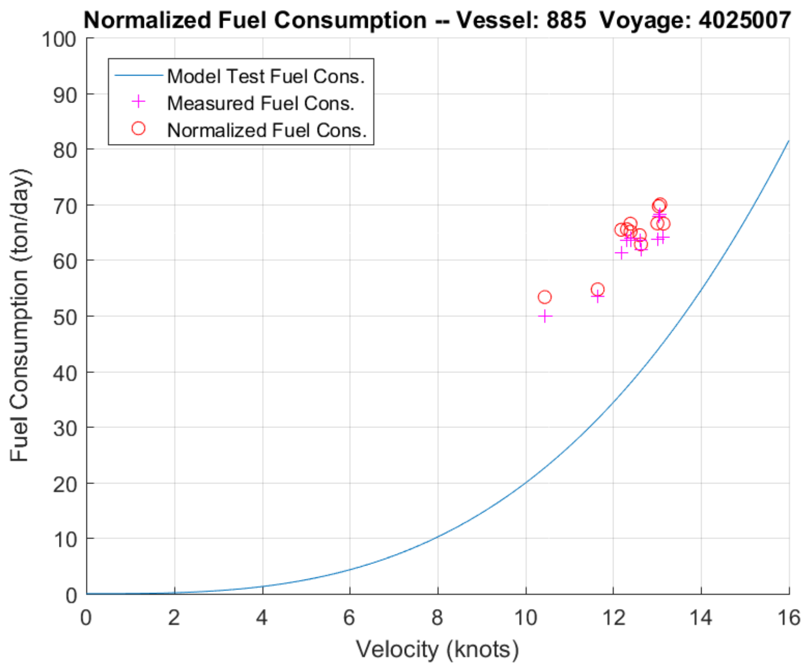
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 22 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 885; Voyage Name: 4025008

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
21	18-Sep-2016 08:00:00	19-Sep-2016 08:00:00	20.62	71.20 40.60	0.00 42.20	0.00 42.20
22	19-Sep-2016 08:00:00	20-Sep-2016 08:00:00	20.62	80.10 40.60	0.00 42.20	0.00 42.20
24	21-Sep-2016 07:00:00	22-Sep-2016 07:00:00	20.62	86.20 40.60	0.00 42.20	0.00 42.20
25	22-Sep-2016 07:00:00	23-Sep-2016 06:00:00	20.62	84.40 40.60	0.00 42.20	0.00 42.20
26	23-Sep-2016 06:00:00	24-Sep-2016 06:00:00	20.62	86.40 40.60	0.00 42.20	0.00 42.20
27	24-Sep-2016 06:00:00	25-Sep-2016 06:00:00	20.62	88.10 40.60	0.00 42.20	0.00 42.20
28	25-Sep-2016 06:00:00	26-Sep-2016 05:00:00	20.62	84.60 40.60	0.00 42.20	0.00 42.20

AIS Calculated Data:

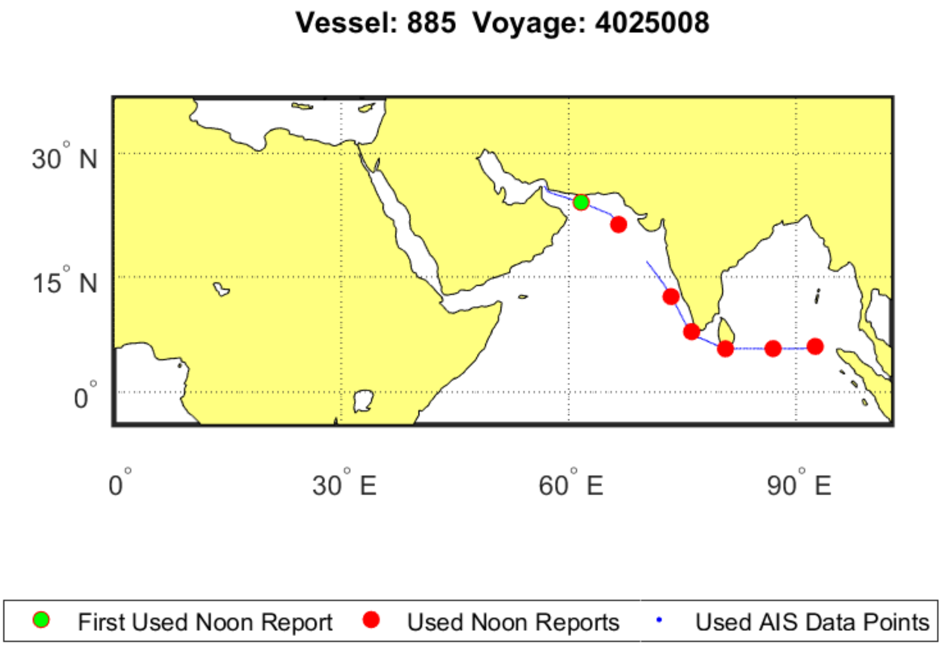
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
21	24	312	315	13.13	1842.0	68.54	
22	24	325	321	13.38	2047.2	77.65	
24	24	342	337	14.02	2155.2	85.52	
25	23	317	318	13.81	2221.5	86.88	
26	24	313	321	13.39	2168.7	89.55	**
27	24	374	348	14.49	2164.0	89.04	
28	23	331	327	14.20	2182.5	87.75	

Filtered Data:

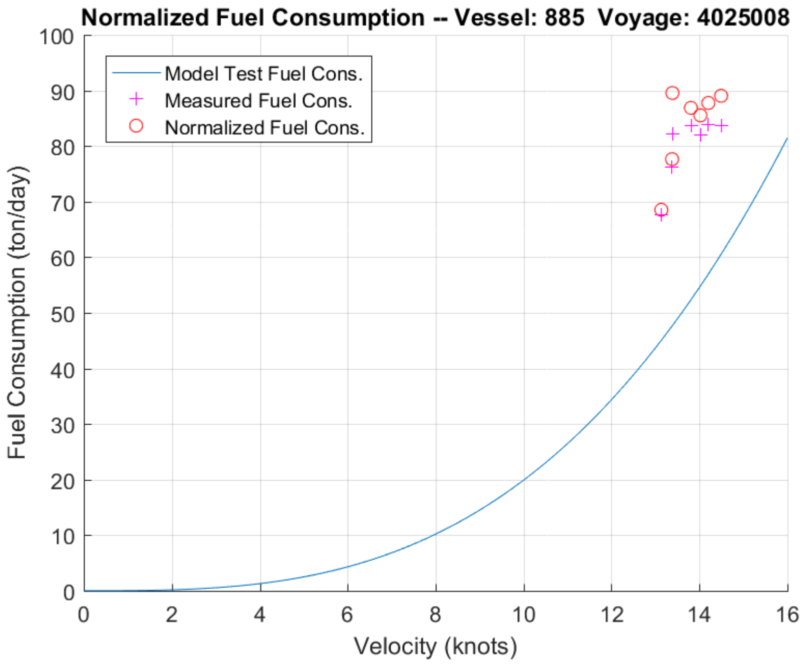
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.

Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to inconsistent AIS/NR lengths.
Noon Report 20 filtered out due to inconsistent AIS/NR lengths.
Noon Report 23 filtered out due to inconsistent AIS/NR lengths.
Noon Report 29 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 885; Voyage Name: 4025009

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
15	01-Nov-2016 09:00:00	02-Nov-2016 09:00:00	20.90	73.60 40.60	0.00 42.20	0.00 42.20
16	02-Nov-2016 09:00:00	03-Nov-2016 08:00:00	20.90	71.10 40.60	0.00 42.20	0.00 42.20
17	03-Nov-2016 08:00:00	04-Nov-2016 08:00:00	20.90	74.20 40.60	0.00 42.20	0.00 42.20
19	05-Nov-2016 07:00:00	06-Nov-2016 07:00:00	20.90	73.70 40.60	0.00 42.20	0.00 42.20
20	06-Nov-2016 07:00:00	07-Nov-2016 07:00:00	20.90	74.30 40.60	0.00 42.20	0.00 42.20
21	07-Nov-2016 07:00:00	08-Nov-2016 06:00:00	20.90	71.20 40.60	0.00 42.20	0.00 42.20

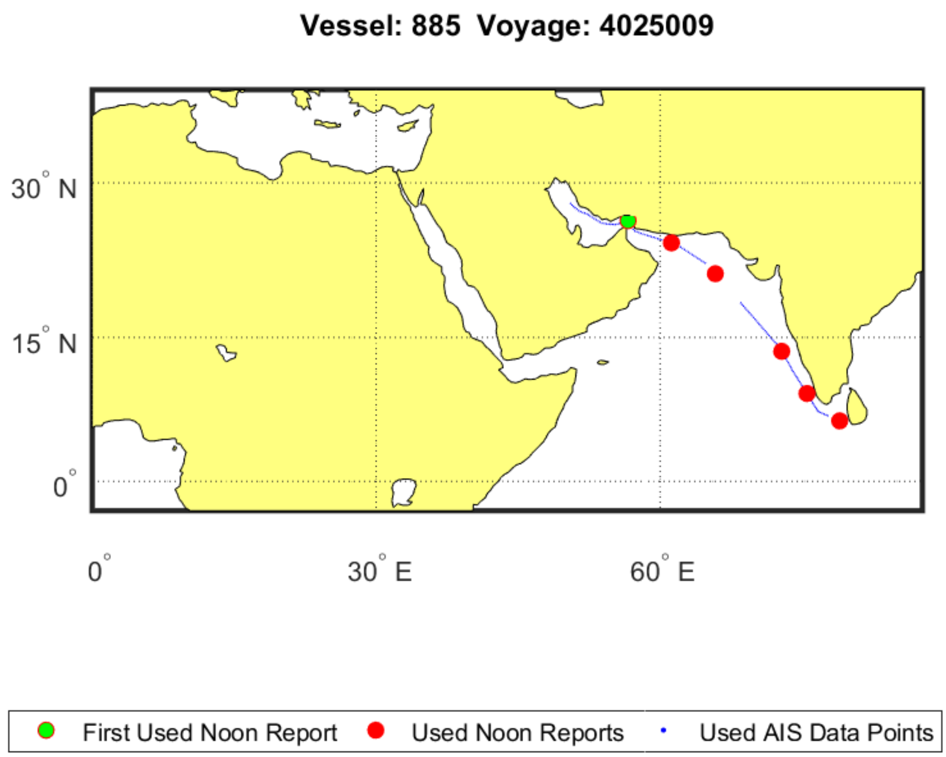
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
15	24	300	301	12.56	1975.6	70.35	
16	23	289	294	12.78	1956.2	70.90	
17	24	313	310	12.92	1948.4	71.27	
19	24	314	312	13.01	1935.8	71.27	
20	24	301	307	12.79	1982.1	71.77	
21	23	283	296	12.89	1961.9	71.61	

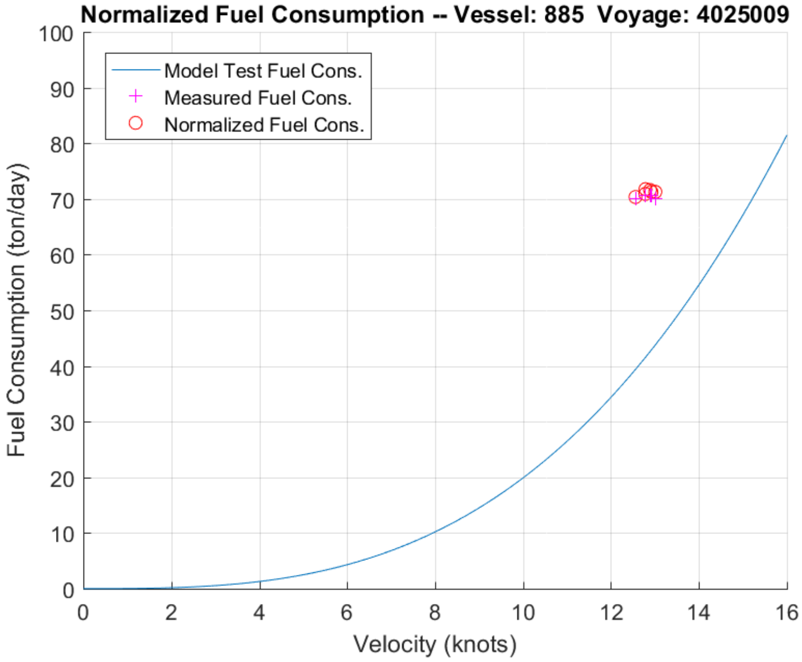
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.
Noon Report 18 filtered out due to inconsistent AIS/NR lengths.
Noon Report 22 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 889; Voyage Name: 4026003

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
23	17-Mar-2016 11:00:00	18-Mar-2016 12:00:00	21.30	78.10 40.30	0.00 42.20	0.00 42.20
24	18-Mar-2016 12:00:00	19-Mar-2016 13:00:00	21.30	78.40 40.30	0.00 42.20	0.00 42.20
25	19-Mar-2016 13:00:00	20-Mar-2016 14:00:00	21.30	77.80 40.30	0.00 42.20	0.00 42.20
26	20-Mar-2016 14:00:00	21-Mar-2016 14:00:00	21.30	74.70 40.30	0.00 42.20	0.00 42.20
27	21-Mar-2016 14:00:00	22-Mar-2016 15:00:00	21.30	77.40 40.30	0.00 42.20	0.00 42.20
28	22-Mar-2016 15:00:00	23-Mar-2016 15:00:00	21.30	68.30 40.30	0.00 42.20	0.00 42.20
29	23-Mar-2016 15:00:00	24-Mar-2016 15:00:00	21.30	67.50 40.30	0.00 42.20	0.00 42.20
30	24-Mar-2016 15:00:00	25-Mar-2016 16:00:00	21.30	72.63 40.30	0.00 42.20	0.00 42.20
31	25-Mar-2016 16:00:00	26-Mar-2016 16:00:00	21.30	65.20 40.30	0.00 42.20	0.00 42.20
32	26-Mar-2016 16:00:00	27-Mar-2016 17:00:00	21.30	65.20 40.30	0.00 42.20	0.00 42.20
33	27-Mar-2016 17:00:00	28-Mar-2016 17:00:00	21.30	66.40 40.30	0.00 42.20	0.00 42.20

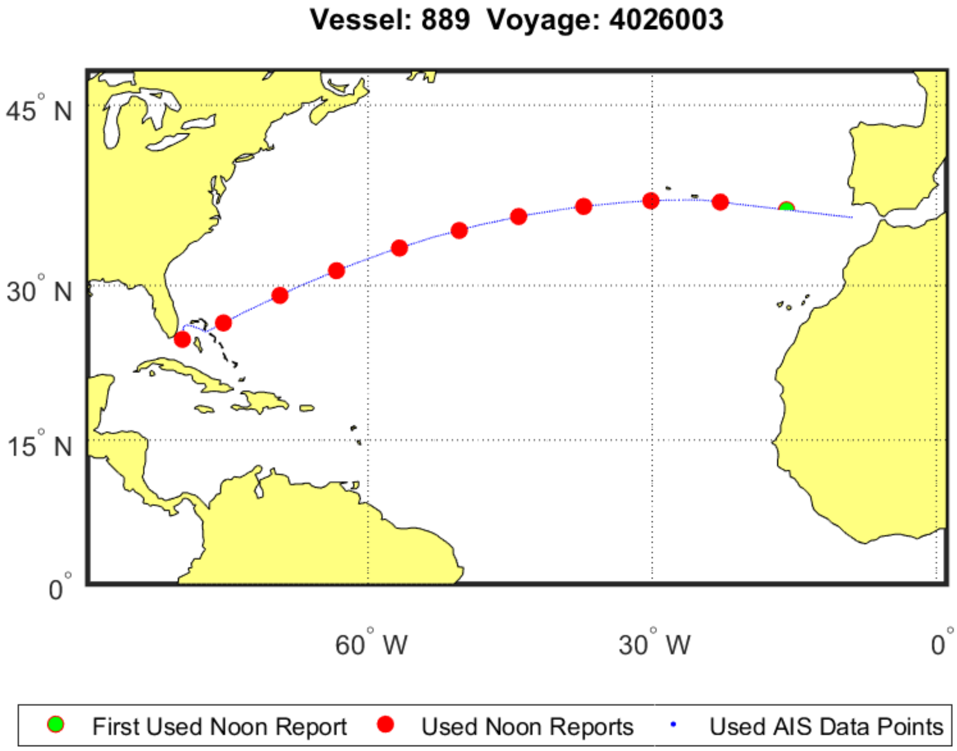
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
23	25	329	327	13.07	1689.1	62.67	
24	25	339	338	13.50	1548.5	59.19	
25	25	350	351	14.04	1670.0	66.40	
26	24	341	340	14.18	1627.5	65.37	
27	25	336	344	13.77	1634.7	63.78	
28	24	315	313	13.02	1295.0	47.85	
29	24	328	322	13.42	1506.1	57.39	
30	25	358	351	14.05	1634.0	64.99	
31	24	339	337	14.06	1530.8	60.93	
32	25	352	357	14.30	1452.9	58.87	
33	24	322	337	14.06	1548.9	61.70	

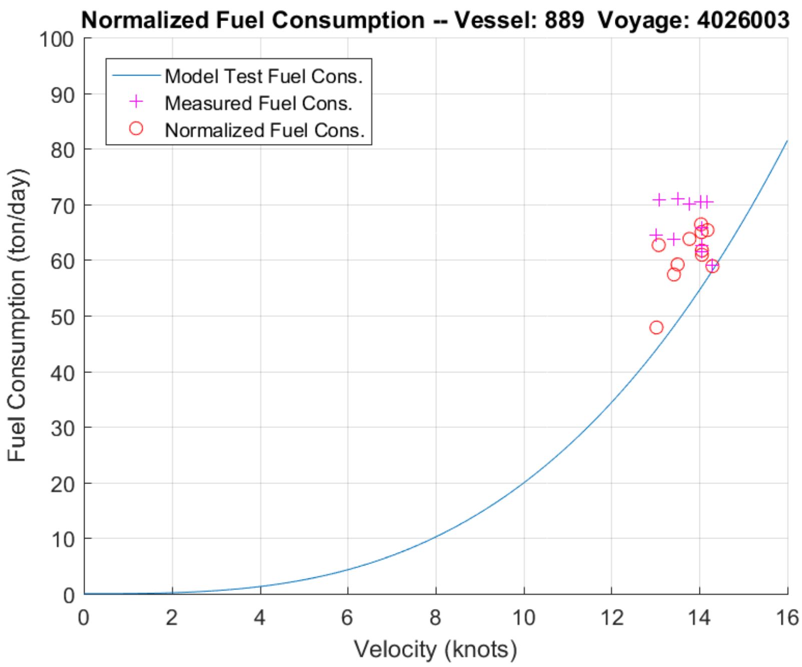
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 35 filtered out manually.
Noon Report 22 filtered out due to inconsistent AIS/NR lengths.
Noon Report 34 filtered out due to inconsistent AIS/NR lengths.
Noon Report 19 filtered out due to lack of AIS data.
Noon Report 20 filtered out due to lack of AIS data.
Noon Report 21 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1501L

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
2	31-Dec-2015 09:00:00	01-Jan-2016 09:00:00	20.70	77.10 40.31	0.00 42.20	0.00 42.20
3	01-Jan-2016 09:00:00	02-Jan-2016 08:00:00	20.60	72.90 40.31	0.00 42.20	0.00 42.20
4	02-Jan-2016 08:00:00	03-Jan-2016 07:00:00	20.60	72.70 40.31	0.00 42.20	0.00 42.20
5	03-Jan-2016 07:00:00	04-Jan-2016 07:00:00	20.60	74.80 40.31	0.00 42.20	0.00 42.20
6	04-Jan-2016 07:00:00	05-Jan-2016 07:00:00	20.60	74.80 40.31	0.00 42.20	0.00 42.20
7	05-Jan-2016 07:00:00	06-Jan-2016 07:00:00	20.50	74.50 40.31	0.00 42.20	0.00 42.20
8	06-Jan-2016 07:00:00	07-Jan-2016 06:00:00	20.50	72.80 40.31	0.00 42.20	0.00 42.20
9	07-Jan-2016 06:00:00	08-Jan-2016 06:00:00	20.40	76.40 40.31	0.00 42.20	0.00 42.20
10	08-Jan-2016 06:00:00	09-Jan-2016 06:00:00	20.30	76.00 40.31	0.00 42.20	0.00 42.20

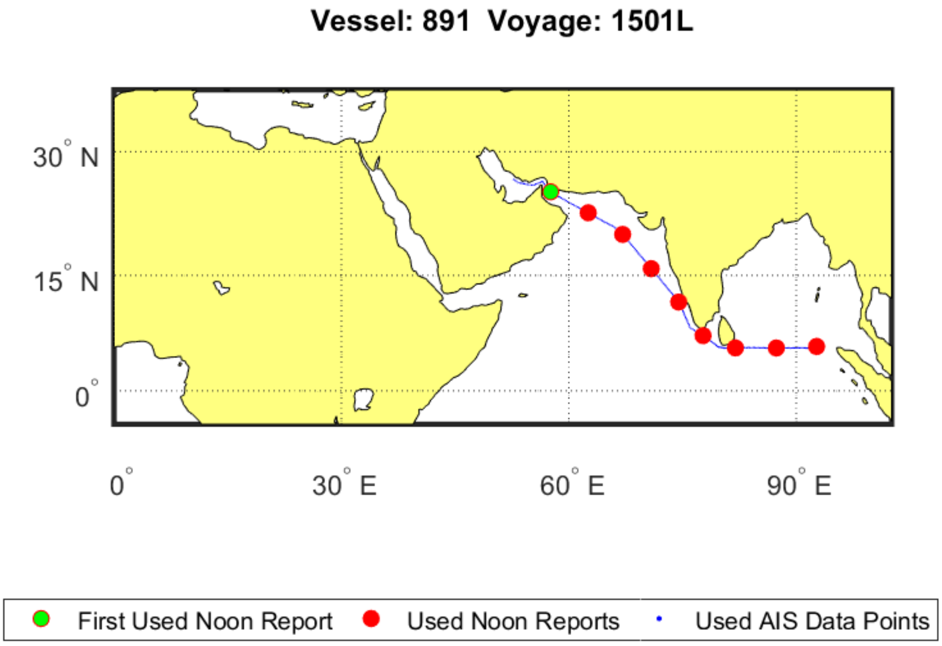
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
2	24	323	327	13.63	1895.8	73.34	
3	23	310	314	13.66	1865.7	72.21	
4	23	300	303	13.16	1885.8	74.08	
5	24	336	340	14.15	1805.3	72.30	
6	24	331	333	13.85	1840.8	72.25	
7	24	337	348	14.51	1748.1	71.84	
8	23	284	324	14.08	1821.4	72.93	
9	24	323	320	13.32	1919.7	72.53	
10	24	318	325	13.55	1887.1	72.36	

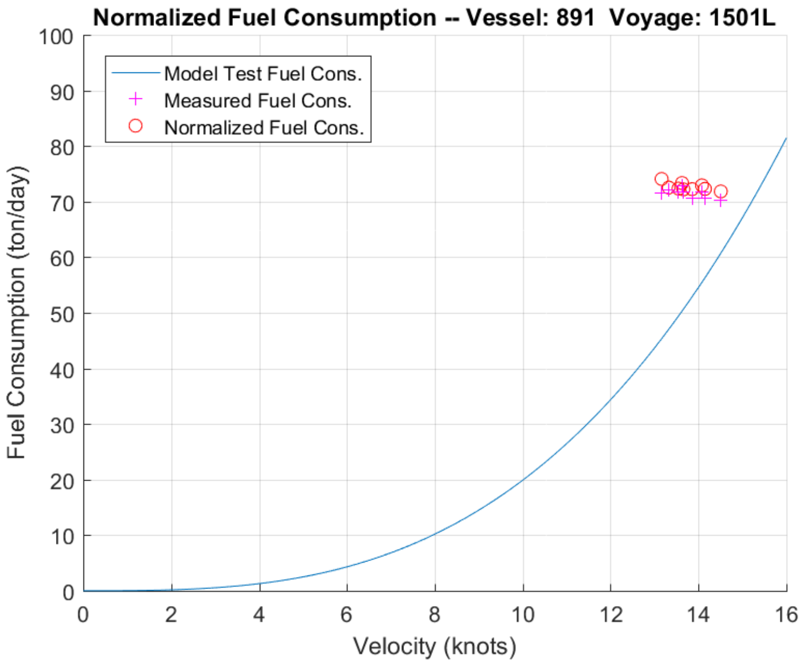
Filtered Data:

Noon Report 1 filtered out due to inconsistent AIS/NR lengths.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1601

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
14	22-Feb-2016 06:00:00	22-Feb-2016 09:00:00	20.60	7.90 40.31	0.00 42.20	0.00 42.20
16	23-Feb-2016 08:00:00	24-Feb-2016 08:00:00	20.60	72.20 40.31	0.00 42.20	0.00 42.20
17	24-Feb-2016 08:00:00	25-Feb-2016 08:00:00	20.60	89.10 40.31	0.00 42.20	0.00 42.20
18	25-Feb-2016 08:00:00	26-Feb-2016 08:00:00	20.60	87.90 40.31	0.00 42.20	0.00 42.20
19	26-Feb-2016 08:00:00	27-Feb-2016 07:00:00	20.60	79.60 40.31	0.00 42.20	0.00 42.20
20	27-Feb-2016 07:00:00	28-Feb-2016 07:00:00	20.60	87.20 40.31	0.00 42.20	0.00 42.20
21	28-Feb-2016 07:00:00	29-Feb-2016 06:00:00	20.55	85.30 40.31	0.00 42.20	0.00 42.20
22	29-Feb-2016 06:00:00	01-Mar-2016 06:00:00	20.55	87.60 40.31	0.00 42.20	0.00 42.20
23	01-Mar-2016 06:00:00	02-Mar-2016 05:00:00	20.55	85.90 40.31	0.00 42.20	0.00 42.20
25	03-Mar-2016 05:00:00	03-Mar-2016 13:00:00	20.55	33.00 40.31	0.00 42.20	0.00 42.20

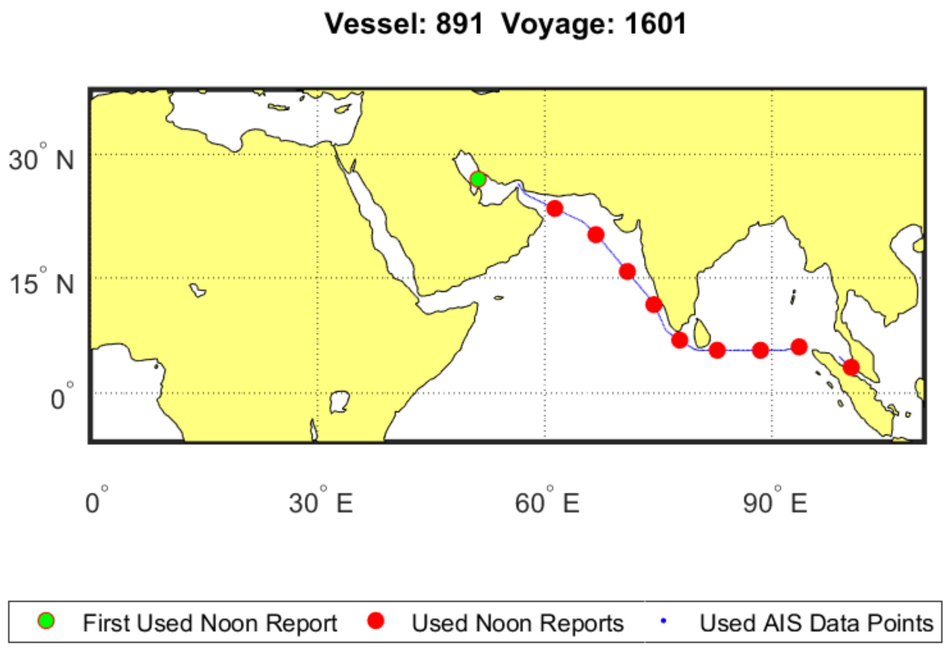
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
14	3	39	40	13.24	1575.6	59.05	
16	24	328	333	13.88	1753.2	69.02	
17	24	363	362	15.07	1998.7	85.31	
18	24	365	360	15.01	1989.2	84.59	
19	23	327	325	14.12	1934.1	83.63	
20	24	355	360	14.99	1969.8	83.61	
21	23	318	342	14.89	2012.1	84.97	
22	24	340	342	14.25	2057.8	83.03	
23	23	308	328	14.27	2090.0	84.65	
25	8	115	116	14.55	2318.3	95.46	

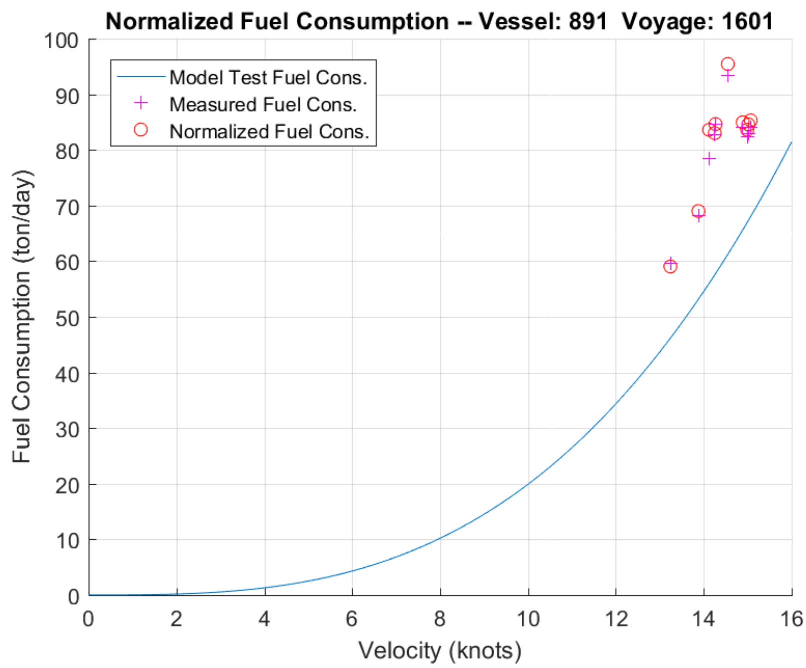
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 15 filtered out due to inconsistent AIS/NR lengths.
Noon Report 24 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1602 / 0011

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
1	22-Mar-2016 09:00:00	23-Mar-2016 08:00:00	21.85	65.70 40.31	0.00 42.20	0.00 42.20
3	24-Mar-2016 08:00:00	25-Mar-2016 08:00:00	21.85	46.80 40.31	0.00 42.20	0.00 42.20
4	25-Mar-2016 08:00:00	26-Mar-2016 08:00:00	21.85	70.30 40.31	0.00 42.20	0.00 42.20
5	26-Mar-2016 08:00:00	27-Mar-2016 09:00:00	21.85	78.90 40.31	0.00 42.20	0.00 42.20
8	30-Mar-2016 09:00:00	31-Mar-2016 10:00:00	21.80	81.40 40.31	0.00 42.20	0.00 42.20
9	31-Mar-2016 10:00:00	01-Apr-2016 10:00:00	21.80	74.50 40.31	0.00 42.20	0.00 42.20
10	01-Apr-2016 10:00:00	01-Apr-2016 14:00:00	21.80	15.50 40.31	0.00 42.20	0.00 42.20

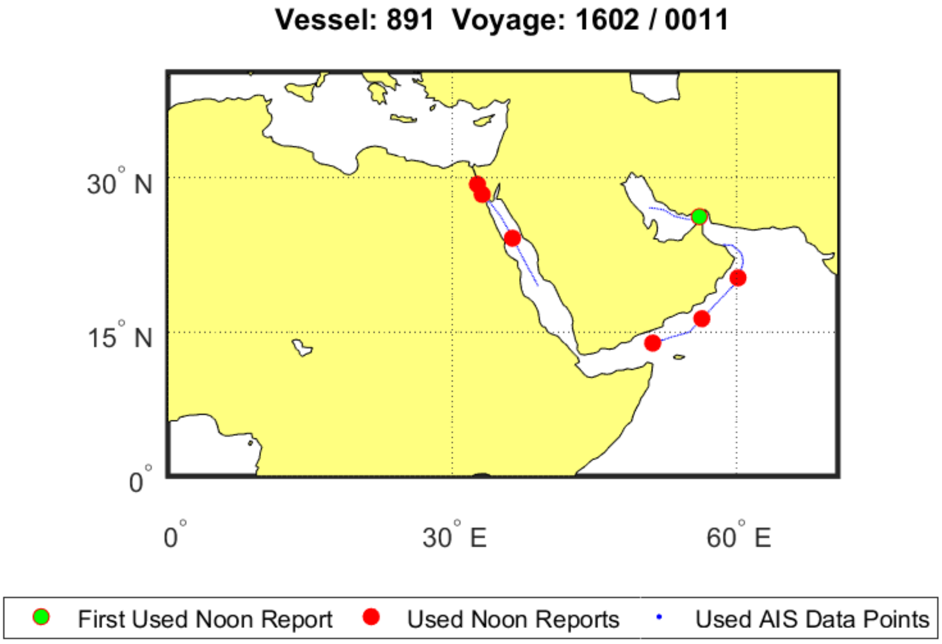
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
1	23	301	299	13.00	1714.7	63.24	
3	24	273	272	11.33	1331.6	43.35	**
4	24	329	328	13.67	1688.2	65.62	
5	25	344	346	13.85	1813.6	71.15	
8	25	320	317	12.66	1958.8	70.29	**
9	24	302	302	12.60	1863.2	66.65	**
10	4	52	52	13.04	2305.6	85.11	**

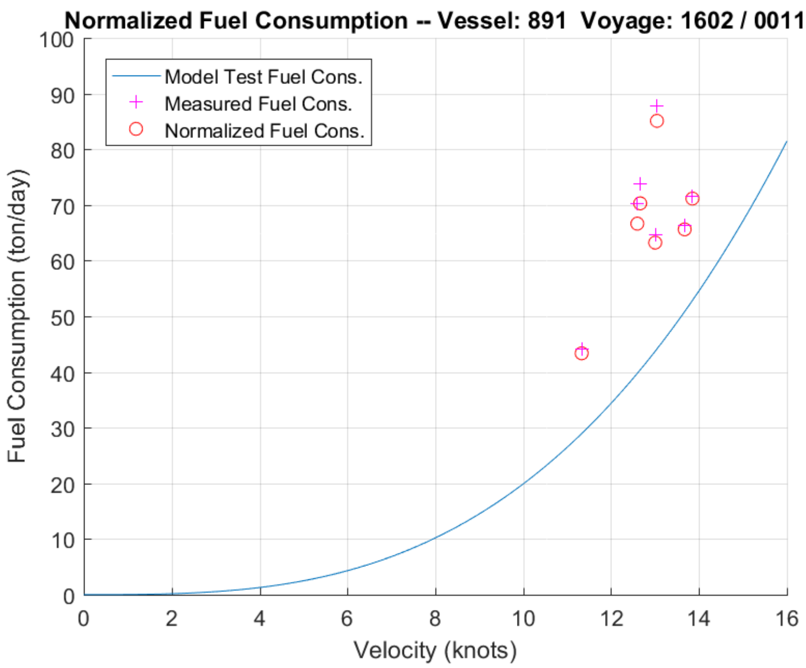
Filtered Data:

Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1603/0012 SHELL VOY

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
3	13-May-2016 08:00:00	14-May-2016 07:00:00	20.90	65.80 40.31	0.00 42.20	0.00 42.20
4	14-May-2016 07:00:00	15-May-2016 07:00:00	20.90	68.70 40.31	0.00 42.20	0.00 42.20
5	15-May-2016 07:00:00	16-May-2016 07:00:00	20.50	68.10 40.31	0.00 42.20	0.00 42.20
8	18-May-2016 06:00:00	19-May-2016 06:00:00	20.40	70.50 40.31	0.00 42.20	0.00 42.20
9	19-May-2016 06:00:00	20-May-2016 06:00:00	20.40	63.30 40.31	0.00 42.20	0.00 42.20
10	20-May-2016 06:00:00	21-May-2016 06:00:00	20.40	56.20 40.31	0.00 42.20	0.00 42.20
11	21-May-2016 06:00:00	22-May-2016 05:00:00	20.40	51.30 40.31	0.00 42.20	0.00 42.20
12	22-May-2016 05:00:00	23-May-2016 04:00:00	20.40	44.70 40.31	0.00 42.20	0.00 42.20

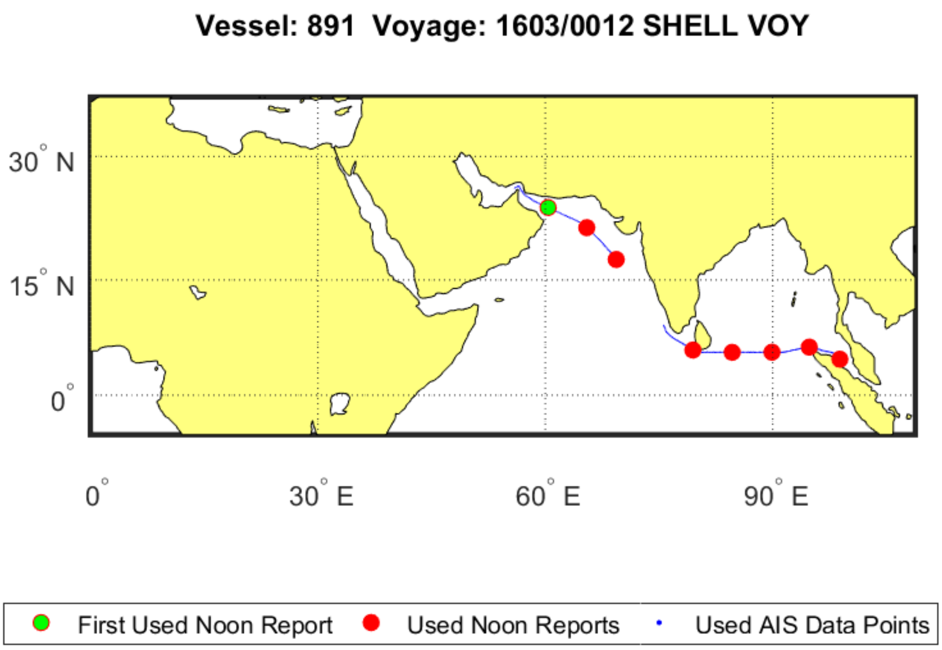
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
3	23	305	303	13.18	1765.1	66.03	
4	24	320	316	13.17	1766.2	65.89	
5	24	325	319	13.30	1771.2	66.77	
8	24	313	311	12.96	1897.3	69.70	
9	24	313	302	12.57	1796.1	64.12	
10	24	312	291	12.13	1629.9	56.18	
11	23	297	288	12.50	1496.5	53.15	
12	23	266	244	10.62	1454.8	46.43	

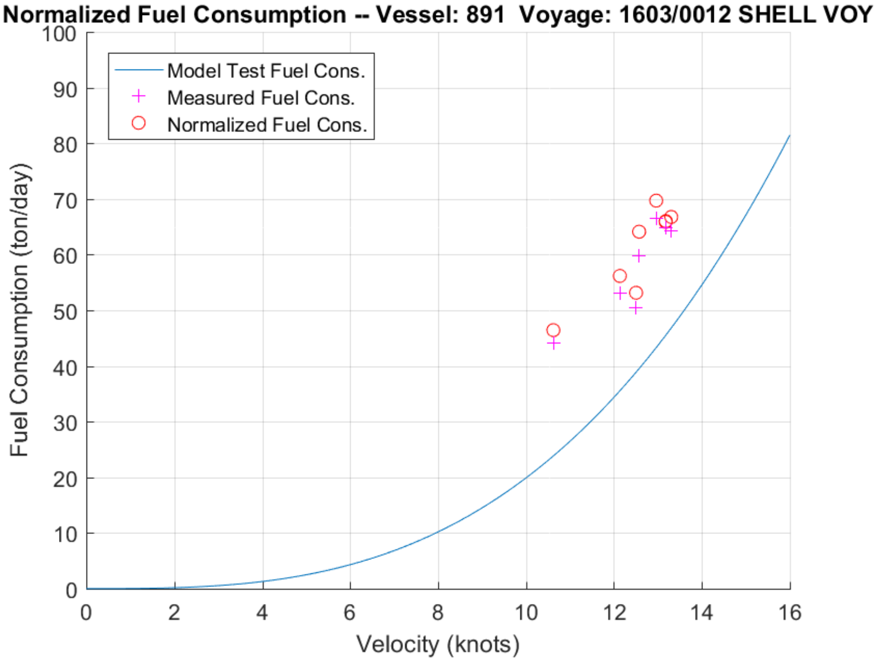
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1604/0013

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
23	15-Jul-2016 05:00:00	15-Jul-2016 09:00:00	21.00	11.80 40.31	0.00 42.20	0.00 42.20
24	15-Jul-2016 09:00:00	16-Jul-2016 08:00:00	21.00	65.80 40.31	0.00 42.20	0.00 42.20
25	16-Jul-2016 08:00:00	16-Jul-2016 23:00:00	21.00	44.80 40.31	0.00 42.20	0.00 42.20
28	19-Jul-2016 08:00:00	20-Jul-2016 09:00:00	21.00	97.60 40.31	0.00 42.20	0.00 42.20
29	20-Jul-2016 09:00:00	21-Jul-2016 09:00:00	21.00	93.80 40.31	0.00 42.20	0.00 42.20
30	21-Jul-2016 09:00:00	22-Jul-2016 09:00:00	21.00	93.10 40.31	0.00 42.20	0.00 42.20
31	22-Jul-2016 09:00:00	23-Jul-2016 09:00:00	21.00	93.80 40.31	0.00 42.20	0.00 42.20
32	23-Jul-2016 09:00:00	24-Jul-2016 09:00:00	21.00	75.80 40.31	0.00 42.20	0.00 42.20
33	24-Jul-2016 09:00:00	25-Jul-2016 10:00:00	21.00	72.50 40.31	0.00 42.20	0.00 42.20
34	25-Jul-2016 10:00:00	26-Jul-2016 10:00:00	21.00	71.50 40.31	0.00 42.20	0.00 42.20
35	26-Jul-2016 10:00:00	26-Jul-2016 20:00:00	21.00	30.20 40.31	0.00 42.20	0.00 42.20

AIS Calculated Data:

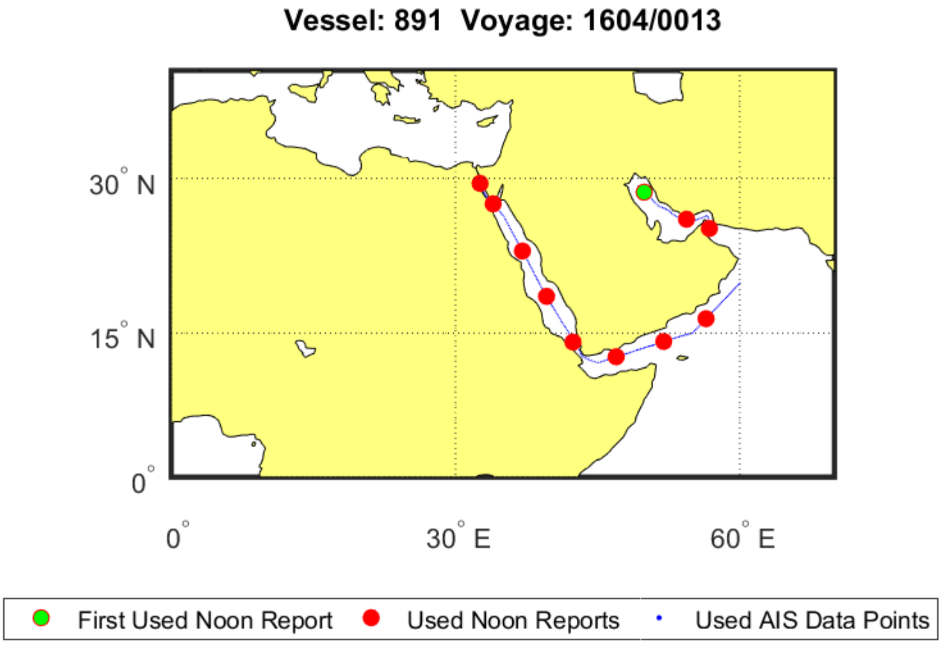
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
23	4	55	54	13.49	1782.9	68.12	
24	23	291	295	12.82	1805.7	65.62	
25	15	188	190	12.66	1897.7	68.22	
28	25	297	302	12.07	1859.4	63.66	
29	24	303	319	13.29	2064.8	77.73	
30	24	307	333	13.87	2233.1	87.92	
31	24	329	333	13.89	2224.5	87.57	**
32	24	319	325	13.52	1884.9	72.30	**
33	25	305	310	12.41	1840.3	67.65	**
34	24	317	319	13.28	1797.7	67.68	**
35	10	129	130	12.95	1845.9	67.79	**

Filtered Data:

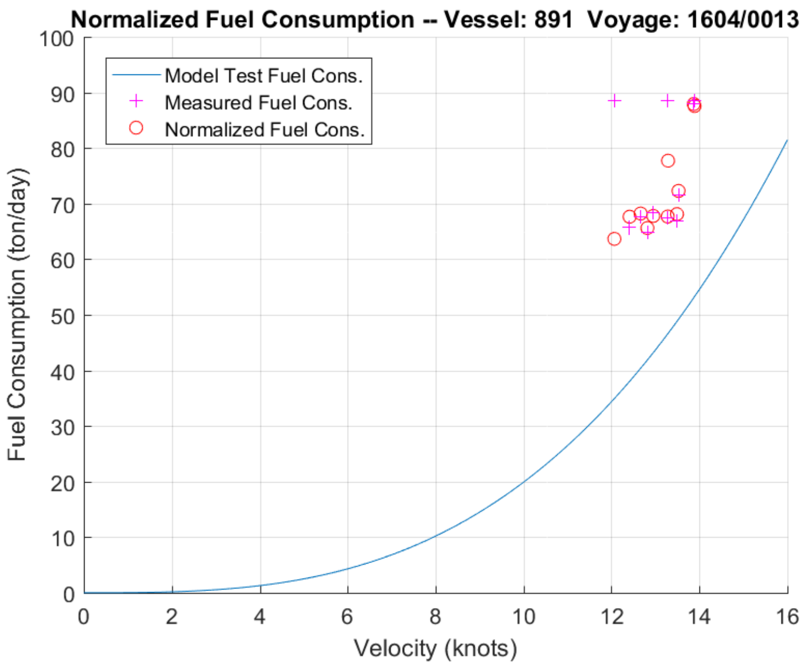
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 20 filtered out due to draft.
Noon Report 21 filtered out due to draft.
Noon Report 22 filtered out due to draft.
Noon Report 36 filtered out due to draft.
Noon Report 37 filtered out due to draft.
Noon Report 38 filtered out due to draft.

Noon Report 26 filtered out due to inconsistent AIS/NR lengths.
Noon Report 27 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1605/0014

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
1	02-Sep-2016 12:00:00	03-Sep-2016 10:00:00	22.00	23.20 40.31	0.00 42.20	0.00 42.20
2	03-Sep-2016 10:00:00	04-Sep-2016 10:00:00	22.00	26.70 40.31	0.00 42.20	0.00 42.20
3	04-Sep-2016 10:00:00	05-Sep-2016 10:00:00	22.00	23.80 40.31	0.00 42.20	0.00 42.20
4	05-Sep-2016 10:00:00	06-Sep-2016 10:00:00	22.00	23.90 40.31	0.00 42.20	0.00 42.20
5	06-Sep-2016 10:00:00	07-Sep-2016 10:00:00	22.00	24.10 40.31	0.00 42.20	0.00 42.20
6	07-Sep-2016 10:00:00	08-Sep-2016 10:00:00	22.00	25.40 40.31	0.00 42.20	0.00 42.20
8	09-Sep-2016 10:00:00	10-Sep-2016 10:00:00	22.00	24.70 40.31	0.00 42.20	0.00 42.20
9	10-Sep-2016 10:00:00	11-Sep-2016 10:00:00	22.00	24.70 40.31	0.00 42.20	0.00 42.20
10	11-Sep-2016 10:00:00	12-Sep-2016 10:00:00	22.00	23.70 40.31	0.00 42.20	0.00 42.20
11	12-Sep-2016 10:00:00	13-Sep-2016 10:00:00	22.00	25.60 40.31	0.00 42.20	0.00 42.20
12	13-Sep-2016 10:00:00	14-Sep-2016 10:00:00	22.00	26.70 40.31	0.00 42.20	0.00 42.20
13	14-Sep-2016 10:00:00	15-Sep-2016 10:00:00	22.00	27.50 40.31	0.00 42.20	0.00 42.20
14	15-Sep-2016 10:00:00	16-Sep-2016 10:00:00	22.00	26.10 40.31	0.00 42.20	0.00 42.20

AIS Calculated Data:

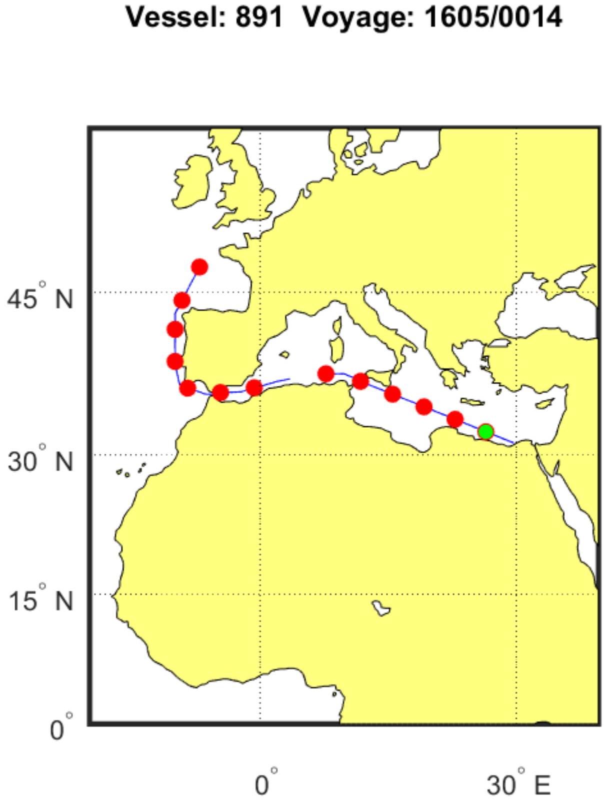
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
1	22	177	176	7.99	1000.2	22.86	**
2	24	195	195	8.13	1034.6	23.96	**
3	24	194	199	8.30	923.2	21.71	**
4	24	193	192	7.99	950.7	21.76	**
5	24	194	199	8.27	908.0	21.49	**
6	24	201	206	8.57	959.1	23.58	**
8	24	204	206	8.57	951.0	23.19	**
9	24	196	200	8.34	946.7	22.75	
10	24	194	203	8.46	868.3	21.14	
11	24	181	188	7.85	957.1	21.54	
12	24	170	176	7.31	1200.2	24.99	
13	24	155	158	6.57	1305.1	24.58	
14	24	184	188	7.82	916.1	20.79	

Filtered Data:

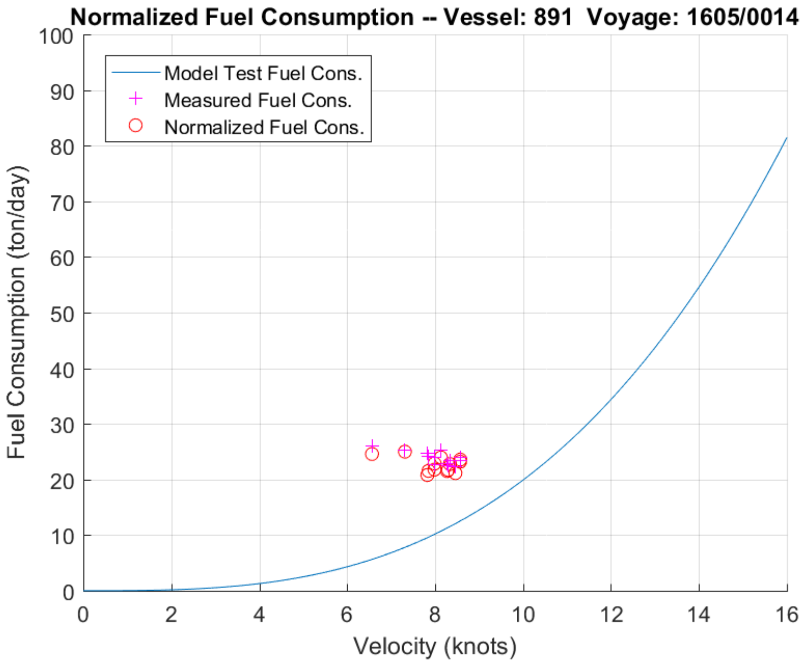
Noon Report 15 filtered out manually.

Noon Report 7 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 891; Voyage Name: 1607/0015

Vessel Type: VLCC

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
9	16-Oct-2016 11:00:00	17-Oct-2016 11:00:00	20.50	71.70 40.31	0.00 42.20	0.00 42.20
10	17-Oct-2016 11:00:00	18-Oct-2016 12:00:00	20.50	73.80 40.31	0.00 42.20	0.00 42.20
11	18-Oct-2016 12:00:00	19-Oct-2016 12:00:00	20.50	71.90 40.31	0.00 42.20	0.00 42.20
12	19-Oct-2016 12:00:00	20-Oct-2016 12:00:00	20.50	70.80 40.31	0.00 42.20	0.00 42.20
13	20-Oct-2016 12:00:00	21-Oct-2016 12:00:00	20.50	70.60 40.31	0.00 42.20	0.00 42.20
14	21-Oct-2016 12:00:00	22-Oct-2016 12:00:00	20.50	70.40 40.31	0.00 42.20	0.00 42.20
15	22-Oct-2016 12:00:00	23-Oct-2016 12:00:00	20.50	70.30 40.31	0.00 42.20	0.00 42.20
16	23-Oct-2016 12:00:00	24-Oct-2016 12:00:00	20.50	71.50 40.31	0.00 42.20	0.00 42.20
17	24-Oct-2016 12:00:00	25-Oct-2016 12:00:00	20.50	71.60 40.31	0.00 42.20	0.00 42.20
18	25-Oct-2016 12:00:00	26-Oct-2016 12:00:00	20.50	71.80 40.31	0.00 42.20	0.00 42.20
19	26-Oct-2016 12:00:00	27-Oct-2016 12:00:00	20.50	71.80 40.31	0.00 42.20	0.00 42.20
20	27-Oct-2016 12:00:00	28-Oct-2016 11:00:00	20.50	68.50 40.31	0.00 42.20	0.00 42.20
21	28-Oct-2016 11:00:00	29-Oct-2016 11:00:00	20.50	71.90 40.31	0.00 42.20	0.00 42.20
22	29-Oct-2016 11:00:00	30-Oct-2016 11:00:00	20.50	73.80 40.31	0.00 42.20	0.00 42.20
24	31-Oct-2016 11:00:00	01-Nov-2016 10:00:00	20.50	67.50 40.31	0.00 42.20	0.00 42.20
26	02-Nov-2016 10:00:00	03-Nov-2016 10:00:00	20.50	69.20 40.31	0.00 42.20	0.00 42.20

27	03-Nov-2016 10:00:00	04-Nov-2016 10:00:00	20.50	68.70 40.31	0.00 42.20	0.00 42.20
28	04-Nov-2016 10:00:00	05-Nov-2016 09:00:00	20.50	67.10 40.31	0.00 42.20	0.00 42.20
29	05-Nov-2016 09:00:00	06-Nov-2016 09:00:00	20.50	70.20 40.31	0.00 42.20	0.00 42.20
30	06-Nov-2016 09:00:00	07-Nov-2016 09:00:00	20.50	70.80 40.31	0.00 42.20	0.00 42.20
31	07-Nov-2016 09:00:00	08-Nov-2016 08:00:00	20.50	68.50 40.31	0.00 42.20	0.00 42.20
32	08-Nov-2016 08:00:00	09-Nov-2016 08:00:00	20.50	69.80 40.31	0.00 42.20	0.00 42.20
33	09-Nov-2016 08:00:00	10-Nov-2016 08:00:00	20.50	70.10 40.31	0.00 42.20	0.00 42.20
34	10-Nov-2016 08:00:00	11-Nov-2016 07:00:00	20.50	68.30 40.31	0.00 42.20	0.00 42.20
35	11-Nov-2016 07:00:00	12-Nov-2016 07:00:00	20.50	70.70 40.31	0.00 42.20	0.00 42.20
38	14-Nov-2016 07:00:00	15-Nov-2016 06:00:00	20.50	69.80 40.31	0.00 42.20	0.00 42.20
39	15-Nov-2016 06:00:00	16-Nov-2016 06:00:00	20.50	71.60 40.31	0.00 42.20	0.00 42.20
40	16-Nov-2016 06:00:00	17-Nov-2016 05:00:00	20.50	68.60 40.31	0.00 42.20	0.00 42.20
41	17-Nov-2016 05:00:00	18-Nov-2016 05:00:00	20.50	69.40 40.31	0.00 42.20	0.00 42.20
42	18-Nov-2016 05:00:00	19-Nov-2016 04:00:00	20.50	60.50 40.31	0.00 42.20	0.00 42.20
43	19-Nov-2016 04:00:00	20-Nov-2016 04:00:00	20.50	66.90 40.31	0.00 42.20	0.00 42.20
44	20-Nov-2016 04:00:00	21-Nov-2016 04:00:00	20.50	70.10 40.31	0.00 42.20	0.00 42.20
45	21-Nov-2016 04:00:00	22-Nov-2016 04:00:00	20.25	58.60 40.31	0.00 42.20	0.00 42.20
46	22-Nov-2016 04:00:00	23-Nov-2016 04:00:00	20.25	59.80 40.31	0.00 42.20	0.00 42.20
48	24-Nov-2016 04:00:00	25-Nov-2016 04:00:00	20.25	63.40 40.31	0.00 42.20	0.00 42.20
49	25-Nov-2016 04:00:00	26-Nov-2016 04:00:00	20.25	70.10 40.31	0.00 42.20	0.00 42.20
50	26-Nov-2016 04:00:00	27-Nov-2016 04:00:00	20.25	71.80 40.31	0.00 42.20	0.00 42.20
51	27-Nov-2016 04:00:00	28-Nov-2016 04:00:00	20.25	72.90 40.31	0.00 42.20	0.00 42.20
52	28-Nov-2016 04:00:00	29-Nov-2016 04:00:00	20.25	71.40 40.31	0.00 42.20	0.00 42.20
53	29-Nov-2016 04:00:00	30-Nov-2016 03:00:00	20.25	63.80 40.31	0.00 42.20	0.00 42.20
54	30-Nov-2016 03:00:00	30-Nov-2016 10:00:00	20.25	16.30 40.31	0.00 42.20	0.00 42.20

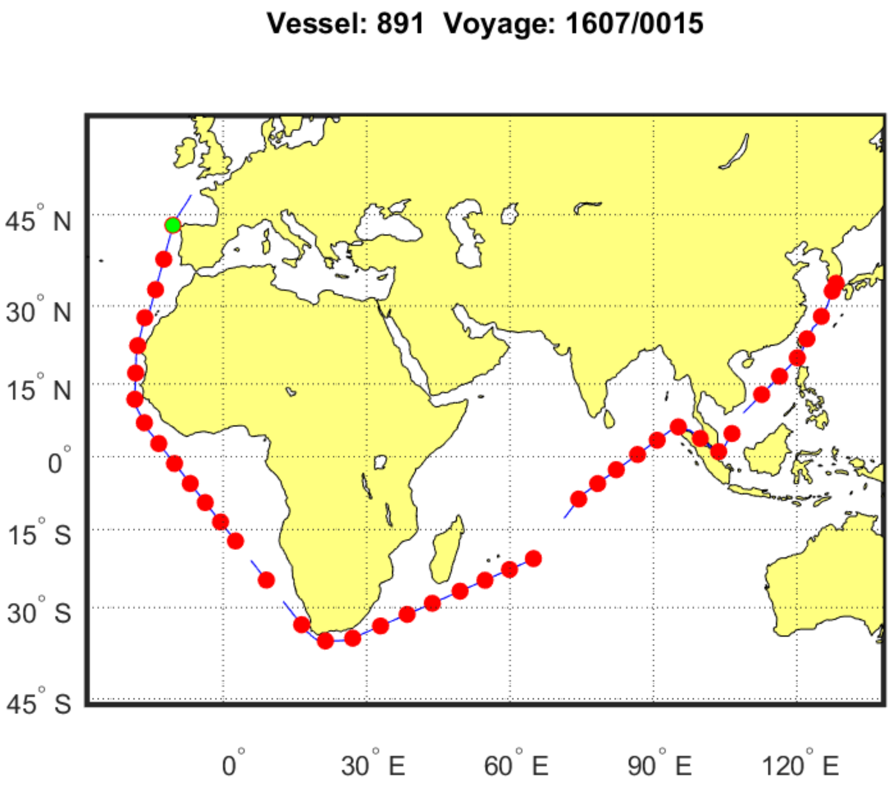
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
9	24	311	309	12.89	1810.0	66.32	
10	25	333	335	13.40	1704.0	64.70	
11	24	319	320	13.31	1806.5	68.10	
12	24	328	326	13.59	1783.9	68.64	
13	24	324	323	13.48	1795.2	68.53	
14	24	322	320	13.34	1812.5	68.51	
15	24	316	320	13.34	1821.2	68.75	
16	24	316	322	13.40	1813.6	68.82	
17	24	316	314	13.10	1842.3	68.31	
18	24	316	311	12.97	1854.0	68.08	
19	24	316	314	13.09	1820.2	67.45	
20	23	299	302	13.15	1809.1	67.41	
21	24	301	300	12.49	1894.0	66.97	
22	24	291	292	12.15	1797.3	61.80	
24	23	286	288	12.53	1781.2	63.17	
26	24	317	317	13.22	1733.5	65.00	
27	24	314	317	13.20	1806.6	67.51	
28	23	282	296	12.85	1885.6	70.02	
29	24	314	319	13.30	1787.2	67.34	
30	24	307	313	13.04	1807.3	66.95	
31	23	297	298	12.95	1856.5	68.17	
32	24	334	322	13.41	1742.7	66.53	
33	24	306	316	13.17	1773.4	66.25	
34	23	306	305	13.27	1788.4	67.21	
35	24	306	309	12.86	1821.4	66.31	
38	23	291	300	13.16	1898.1	70.68	
39	24	305	318	13.24	1832.5	68.74	
40	23	288	302	13.13	1851.7	69.03	
41	24	328	329	13.69	1756.2	68.11	
42	23	303	300	13.06	1682.5	62.25	
43	24	321	323	13.46	1699.6	64.92	
44	24	315	310	12.92	1873.7	68.64	
45	24	290	NaN	NaN	NaN	NaN	**
46	24	292	296	12.32	1619.7	60.73	**
48	24	316	314	13.08	1576.9	58.79	
49	24	309	303	12.62	1621.9	58.00	
50	24	304	308	12.83	1619.8	58.92	
51	24	253	234	9.73	1895.0	53.40	
52	24	303	288	11.99	1713.8	58.51	
53	23	300	293	12.74	1664.2	60.10	
54	7	94	92	13.09	1435.2	53.21	

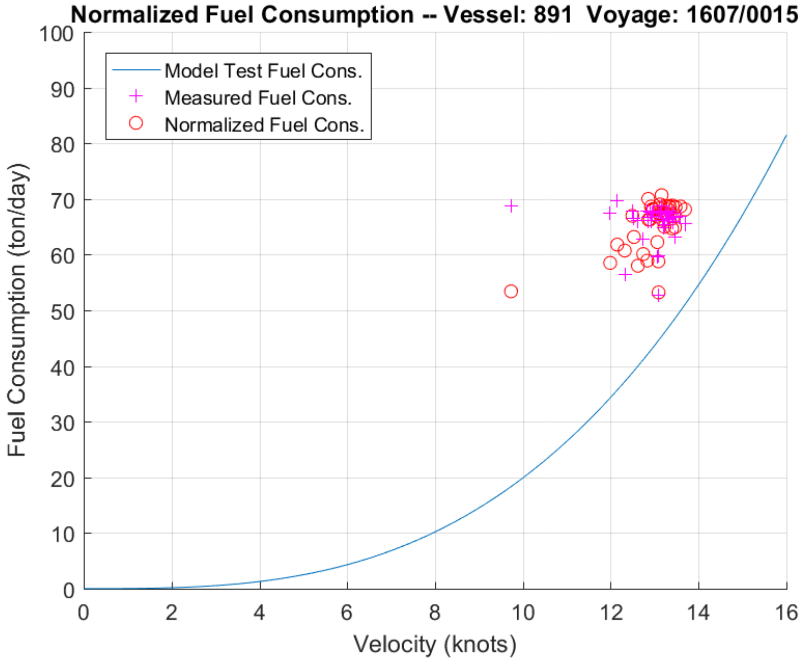
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to fuel use.
Noon Report 5 filtered out due to fuel use.
Noon Report 6 filtered out due to fuel use.
Noon Report 7 filtered out due to fuel use.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.
Noon Report 23 filtered out due to inconsistent AIS/NR lengths.
Noon Report 25 filtered out due to inconsistent AIS/NR lengths.
Noon Report 36 filtered out due to inconsistent AIS/NR lengths.
Noon Report 37 filtered out due to inconsistent AIS/NR lengths.
Noon Report 47 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 12

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
9	07-Dec-2015 18:00:00	08-Dec-2015 18:00:00	12.50	15.90 41.26	0.00 42.20	0.00 42.20
10	08-Dec-2015 18:00:00	09-Dec-2015 18:00:00	12.50	24.10 41.26	0.00 42.20	0.00 42.20
11	09-Dec-2015 18:00:00	10-Dec-2015 17:00:00	12.50	24.50 41.26	0.00 42.20	0.00 42.20
12	10-Dec-2015 17:00:00	11-Dec-2015 17:00:00	12.50	25.10 41.26	0.00 42.20	0.00 42.20
13	11-Dec-2015 17:00:00	12-Dec-2015 16:00:00	12.50	24.00 41.26	0.00 42.20	0.00 42.20
14	12-Dec-2015 16:00:00	13-Dec-2015 16:00:00	12.50	23.90 41.26	0.00 42.20	0.00 42.20
15	13-Dec-2015 16:00:00	14-Dec-2015 15:00:00	12.50	23.70 41.26	0.00 42.20	0.00 42.20
16	14-Dec-2015 15:00:00	15-Dec-2015 15:00:00	12.50	25.10 41.26	0.00 42.20	0.00 42.20
17	15-Dec-2015 15:00:00	16-Dec-2015 14:00:00	12.50	22.80 41.26	0.00 42.20	0.00 42.20
18	16-Dec-2015 14:00:00	17-Dec-2015 14:00:00	12.50	24.40 41.26	0.00 42.20	0.00 42.20
20	18-Dec-2015 13:00:00	19-Dec-2015 13:00:00	12.50	24.10 41.26	0.00 42.20	0.00 42.20
21	19-Dec-2015 13:00:00	20-Dec-2015 12:00:00	12.50	23.20 41.26	0.00 42.20	0.00 42.20
22	20-Dec-2015 12:00:00	21-Dec-2015 12:00:00	12.50	24.70 41.26	0.00 42.20	0.00 42.20
23	21-Dec-2015 12:00:00	22-Dec-2015 12:00:00	12.50	24.10 41.26	0.00 42.20	0.00 42.20

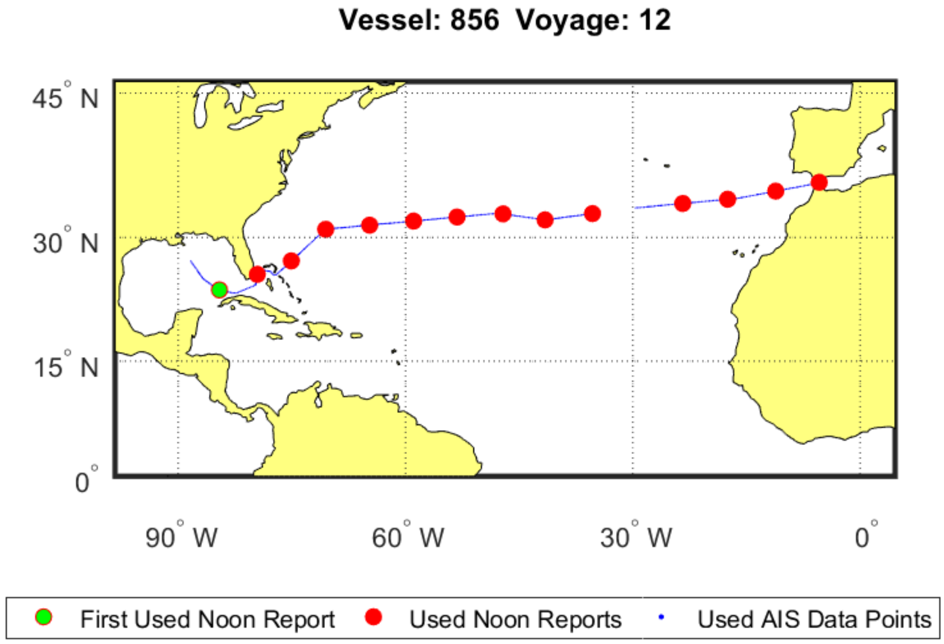
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
9	24	300	295	12.30	332.0	13.15	
10	24	352	319	13.32	477.6	20.50	
11	23	314	310	13.52	494.9	21.50	
12	24	320	318	13.30	462.8	19.80	
13	23	298	306	13.34	490.6	21.05	
14	24	297	294	12.28	466.5	18.42	
15	23	292	292	12.72	537.4	21.97	
16	24	307	307	12.83	581.4	24.00	
17	23	284	280	12.20	591.7	23.23	
18	24	319	311	12.99	558.9	23.34	
20	24	316	309	12.90	580.7	24.07	
21	23	295	296	12.91	548.3	22.76	
22	24	316	313	13.07	520.7	21.86	
23	24	292	290	12.11	NaN	NaN	

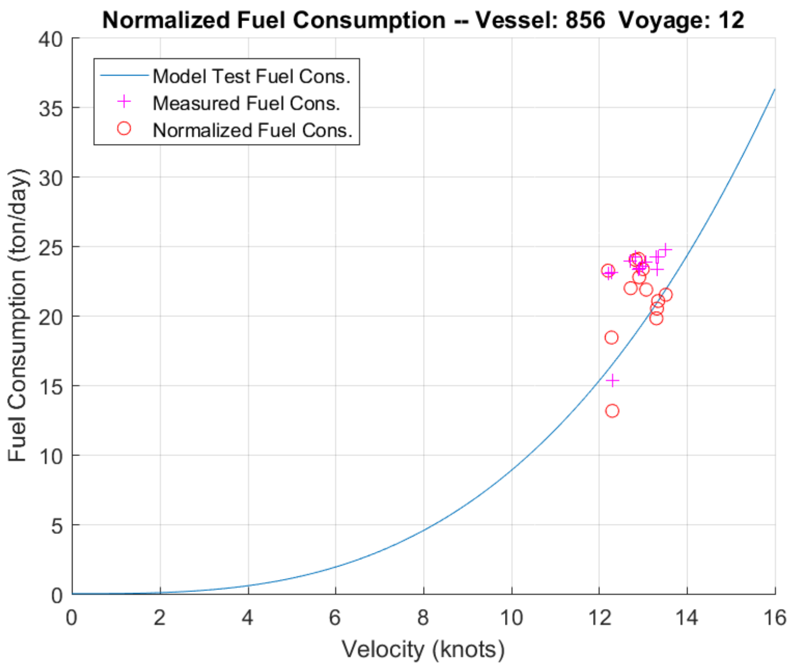
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to fuel use.
Noon Report 19 filtered out due to inconsistent AIS/NR lengths.
Noon Report 24 filtered out due to inconsistent AIS/NR lengths.
Noon Report 25 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 13

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
10	27-Jan-2016 11:00:00	28-Jan-2016 11:00:00	11.00	28.50 41.26	0.00 42.20	0.00 42.20
11	28-Jan-2016 11:00:00	29-Jan-2016 11:00:00	11.00	27.90 41.26	0.00 42.20	0.00 42.20
12	29-Jan-2016 11:00:00	30-Jan-2016 11:00:00	11.00	27.40 41.26	0.00 42.20	0.00 42.20

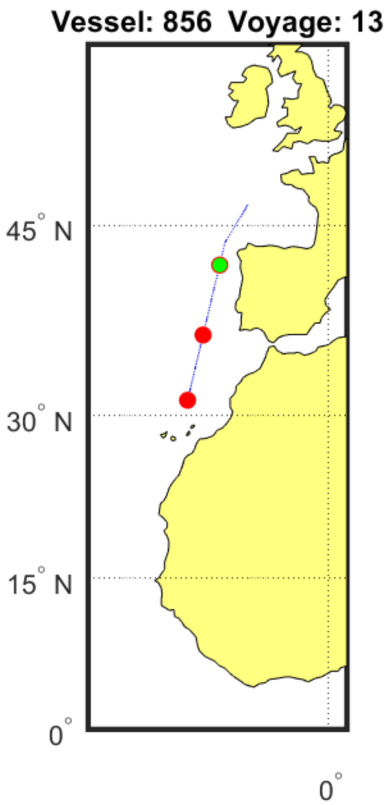
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
10	24	289	290	12.08	655.0	26.91	
11	24	331	330	13.82	631.4	28.03	
12	24	331	332	13.88	652.8	29.09	

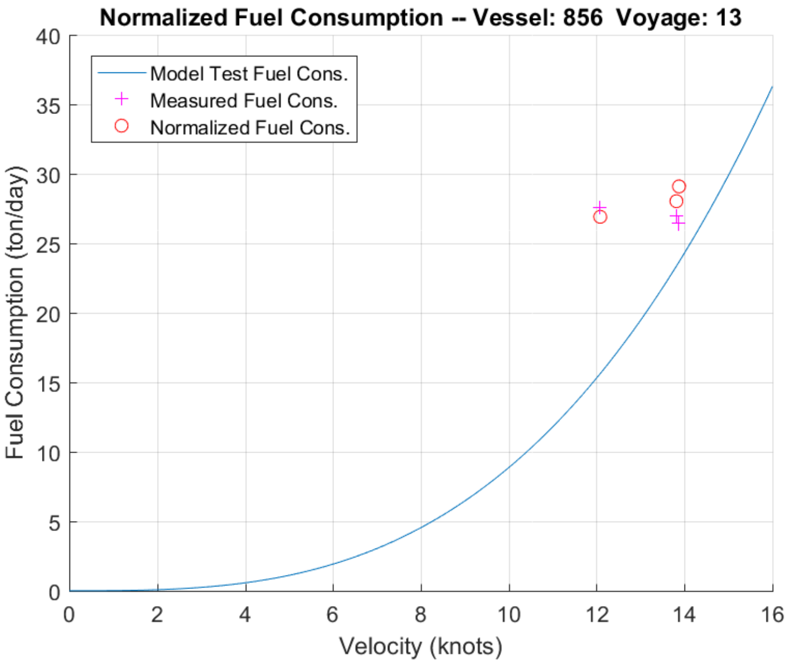
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to fuel use.
Noon Report 7 filtered out due to fuel use.
Noon Report 8 filtered out manually.
Noon Report 9 filtered out manually.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to lack of AIS data.
Noon Report 15 filtered out due to lack of AIS data.
Noon Report 16 filtered out due to lack of AIS data.
Noon Report 17 filtered out due to lack of AIS data.
Noon Report 18 filtered out due to lack of AIS data.
Noon Report 19 filtered out due to lack of AIS data.
Noon Report 20 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 14

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
14	09-Mar-2016 11:00:00	10-Mar-2016 11:00:00	10.30	28.90 41.26	0.00 42.20	0.00 42.20
15	10-Mar-2016 11:00:00	11-Mar-2016 11:00:00	10.30	29.00 41.26	0.00 42.20	0.00 42.20
16	11-Mar-2016 11:00:00	12-Mar-2016 11:00:00	10.30	27.30 41.26	0.00 42.20	0.00 42.20
17	12-Mar-2016 11:00:00	13-Mar-2016 11:00:00	10.30	27.90 41.26	0.00 42.20	0.00 42.20

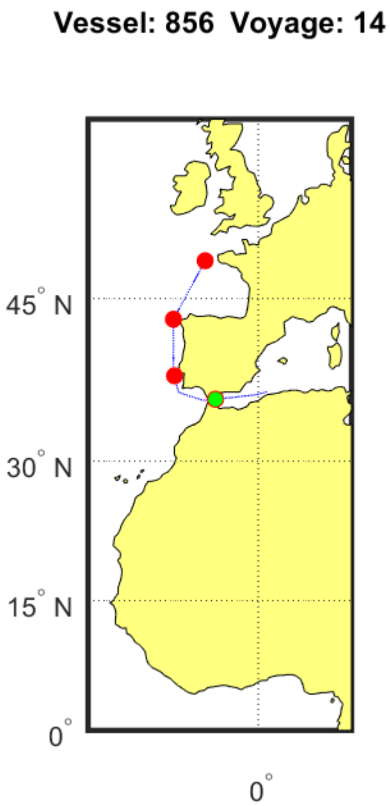
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
14	24	297	315	13.15	555.0	23.59	**
15	24	310	320	13.35	572.3	24.68	
16	24	299	302	12.63	570.9	23.21	
17	24	325	326	13.61	627.0	27.46	

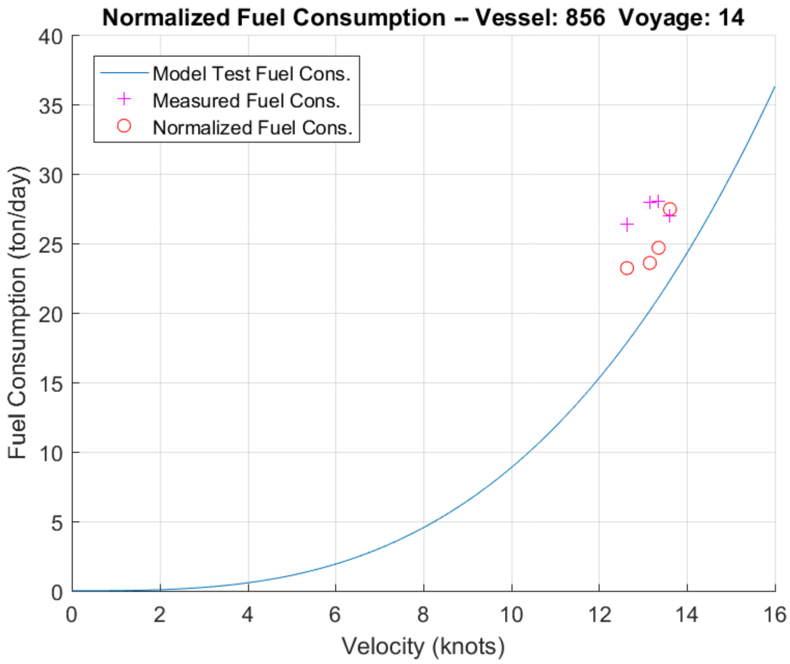
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 18 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 16

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
4	09-Apr-2016 11:00:00	10-Apr-2016 11:00:00	11.60	26.00 41.26	0.00 42.20	0.00 42.20
5	10-Apr-2016 11:00:00	11-Apr-2016 11:00:00	11.60	26.00 41.26	0.00 42.20	0.00 42.20
6	11-Apr-2016 11:00:00	12-Apr-2016 11:00:00	11.60	30.50 41.26	0.00 42.20	0.00 42.20
7	12-Apr-2016 11:00:00	13-Apr-2016 11:00:00	11.60	33.50 41.26	0.00 42.20	0.00 42.20
8	13-Apr-2016 11:00:00	14-Apr-2016 11:00:00	11.60	33.50 41.26	0.00 42.20	0.00 42.20
9	14-Apr-2016 11:00:00	15-Apr-2016 11:00:00	11.60	33.50 41.26	0.00 42.20	0.00 42.20

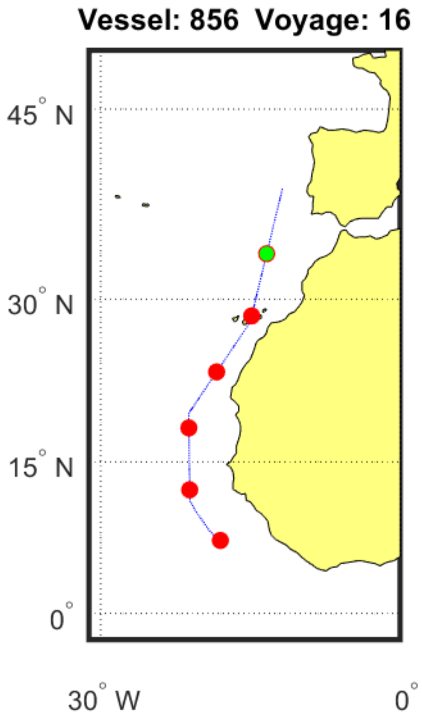
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
4	24	323	322	13.47	578.2	25.01	
5	24	326	324	13.52	573.3	24.91	
6	24	356	355	14.82	606.8	28.96	
7	24	359	357	14.91	677.0	32.44	
8	24	356	355	14.81	692.7	32.97	
9	24	362	355	14.81	676.1	32.16	

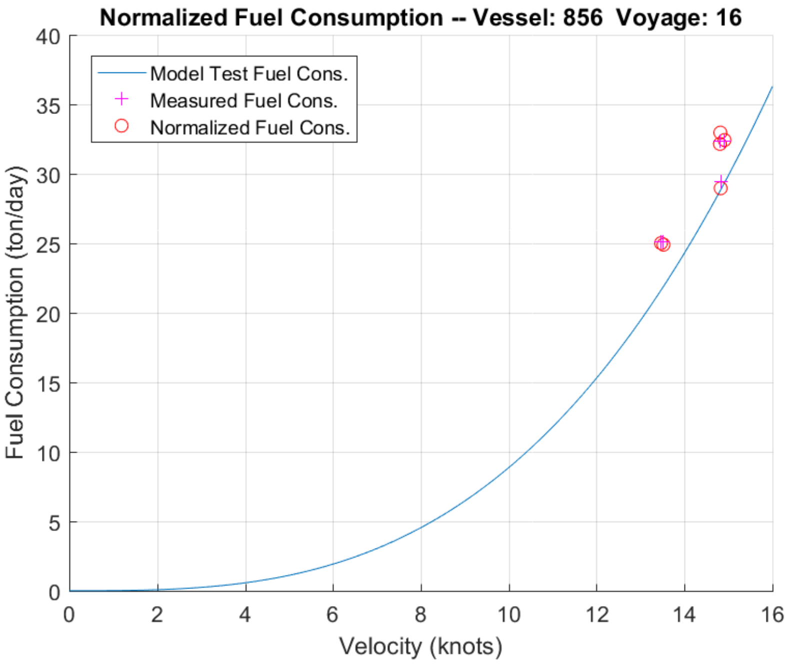
Filtered Data:

Noon Report 2 filtered out manually.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 10 filtered out due to lack of AIS data.
Noon Report 11 filtered out due to lack of AIS data.
Noon Report 12 filtered out due to lack of AIS data.
Noon Report 13 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 17

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
25	28-May-2016 10:00:00	29-May-2016 10:00:00	12.40	23.00 41.26	0.00 42.20	0.00 42.20
26	29-May-2016 10:00:00	30-May-2016 10:00:00	12.40	27.60 41.26	0.00 42.20	0.00 42.20
28	31-May-2016 11:00:00	01-Jun-2016 11:00:00	12.40	26.00 41.26	0.00 42.20	0.00 42.20
29	01-Jun-2016 11:00:00	02-Jun-2016 11:00:00	12.40	26.30 41.26	0.00 42.20	0.00 42.20
31	03-Jun-2016 12:00:00	04-Jun-2016 12:00:00	12.40	26.00 41.26	0.00 42.20	0.00 42.20
32	04-Jun-2016 12:00:00	05-Jun-2016 12:00:00	12.40	27.00 41.26	0.00 42.20	0.00 42.20
33	05-Jun-2016 12:00:00	06-Jun-2016 13:00:00	12.40	28.50 41.26	0.00 42.20	0.00 42.20
34	06-Jun-2016 13:00:00	07-Jun-2016 13:00:00	12.40	27.20 41.26	0.00 42.20	0.00 42.20
35	07-Jun-2016 13:00:00	08-Jun-2016 13:00:00	12.40	27.10 41.26	0.00 42.20	0.00 42.20
37	09-Jun-2016 14:00:00	10-Jun-2016 14:00:00	12.40	26.80 41.26	0.00 42.20	0.00 42.20
38	10-Jun-2016 14:00:00	11-Jun-2016 14:00:00	12.40	29.90 41.26	0.00 42.20	0.00 42.20
39	11-Jun-2016 14:00:00	12-Jun-2016 15:00:00	12.40	31.80 41.26	0.00 42.20	0.00 42.20
40	12-Jun-2016 15:00:00	13-Jun-2016 15:00:00	12.40	30.00 41.26	0.00 42.20	0.00 42.20
41	13-Jun-2016 15:00:00	14-Jun-2016 15:00:00	12.40	28.40 41.26	0.00 42.20	0.00 42.20
42	14-Jun-2016 15:00:00	15-Jun-2016 15:00:00	12.40	28.20 41.26	0.00 42.20	0.00 42.20

AIS Calculated Data:

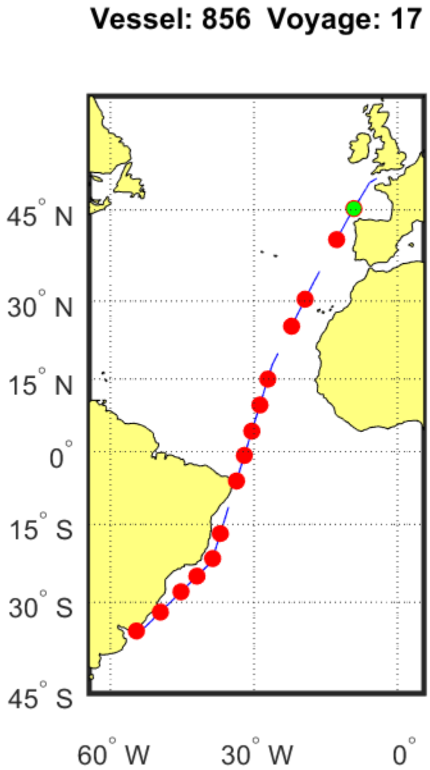
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
25	24	326	325	13.60	421.0	18.48	
26	24	323	323	13.68	532.9	23.43	
28	24	329	330	13.81	519.9	23.06	
29	24	332	332	13.87	529.5	23.59	
31	24	329	328	13.68	551.9	24.26	
32	24	329	335	13.95	554.1	24.83	
33	25	337	348	13.93	557.8	24.98	
34	24	315	324	13.52	563.5	24.52	
35	24	331	324	13.58	561.7	24.51	
37	24	330	329	13.76	516.0	22.82	
38	24	306	303	12.68	573.3	23.47	
39	25	273	270	10.83	637.0	22.22	
40	24	249	249	10.38	589.2	20.00	
41	24	313	306	12.81	483.7	19.99	
42	24	322	329	13.79	551.8	24.51	

Filtered Data:

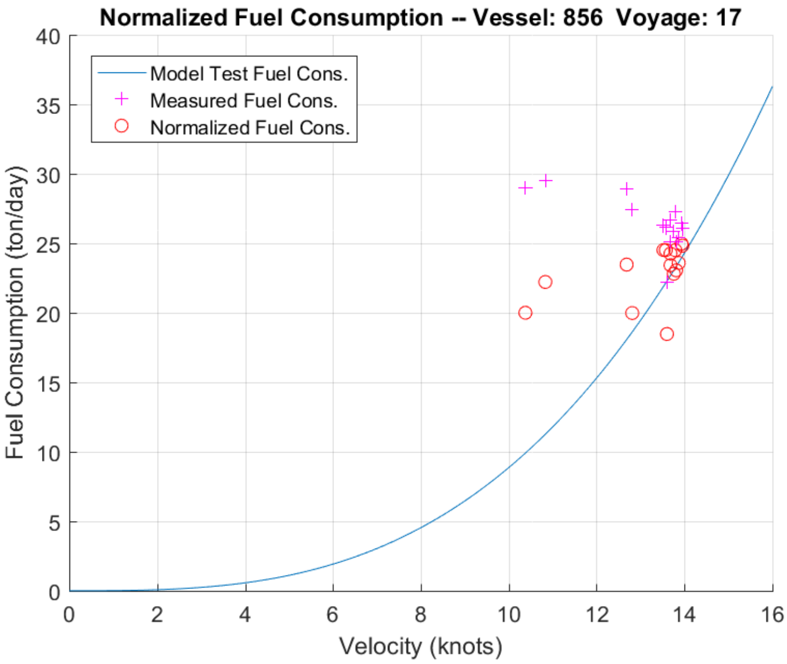
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 20 filtered out due to draft.
Noon Report 21 filtered out due to fuel use.
Noon Report 22 filtered out due to fuel use.
Noon Report 23 filtered out due to fuel use.
Noon Report 24 filtered out due to fuel use.

Noon Report 27 filtered out due to inconsistent AIS/NR lengths.
Noon Report 30 filtered out due to inconsistent AIS/NR lengths.
Noon Report 36 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 18

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
22	17-Jul-2016 10:00:00	18-Jul-2016 10:00:00	11.07	22.60 41.26	0.00 42.20	0.00 42.20
23	18-Jul-2016 10:00:00	19-Jul-2016 10:00:00	11.07	20.50 41.26	0.00 42.20	0.00 42.20
24	19-Jul-2016 10:00:00	20-Jul-2016 10:00:00	11.07	22.60 41.26	0.00 42.20	0.00 42.20
25	20-Jul-2016 10:00:00	21-Jul-2016 10:00:00	11.07	22.90 41.26	0.00 42.20	0.00 42.20
26	21-Jul-2016 10:00:00	22-Jul-2016 11:00:00	11.07	23.20 41.26	0.00 42.20	0.00 42.20
27	22-Jul-2016 11:00:00	23-Jul-2016 11:00:00	11.07	22.70 41.26	0.00 42.20	0.00 42.20
29	24-Jul-2016 12:00:00	25-Jul-2016 12:00:00	11.35	22.60 41.26	0.00 42.20	0.00 42.20

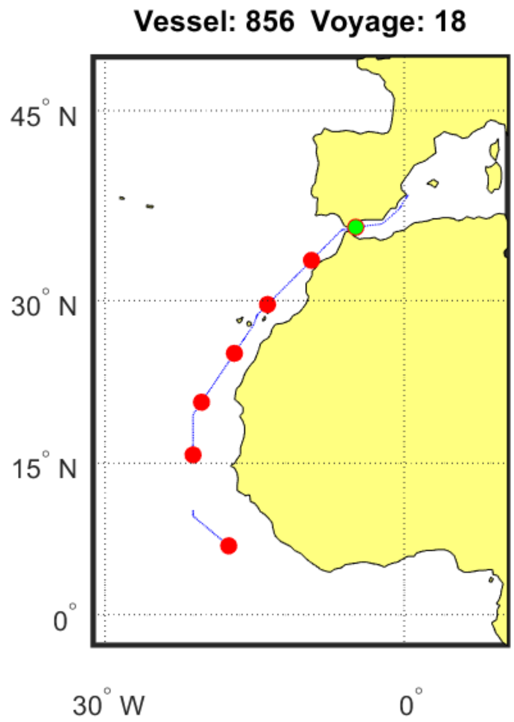
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
22	24	313	316	13.20	542.0	22.99	**
23	24	284	287	11.99	521.7	21.25	
24	24	318	313	13.06	550.0	23.07	
25	24	313	309	13.00	567.8	23.77	
26	25	323	320	12.83	536.6	22.14	
27	24	313	308	12.85	519.8	21.46	
29	24	310	298	12.46	537.4	21.59	

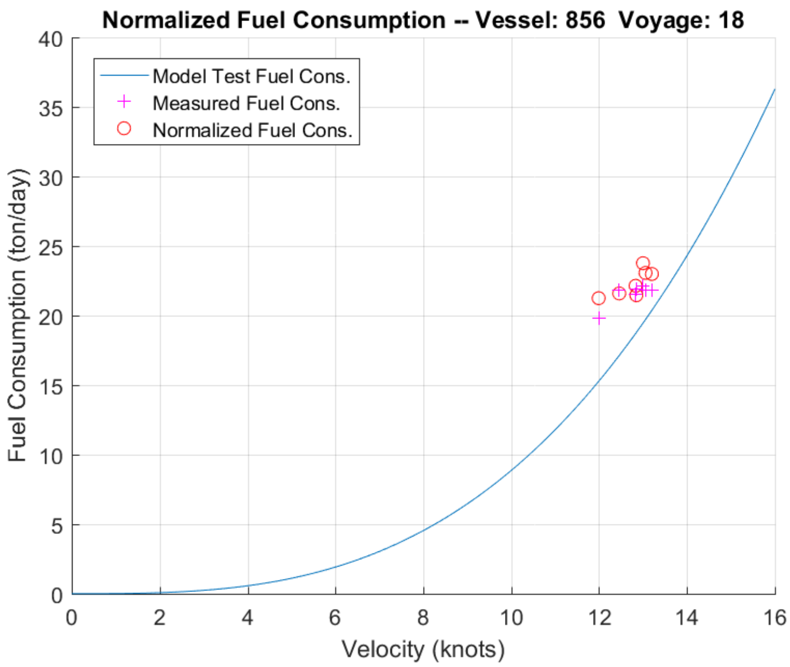
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 21 filtered out due to inconsistent AIS/NR lengths.
Noon Report 28 filtered out due to inconsistent AIS/NR lengths.
Noon Report 30 filtered out due to inconsistent AIS/NR lengths.
Noon Report 34 filtered out due to inconsistent AIS/NR lengths.
Noon Report 20 filtered out due to lack of AIS data.
Noon Report 31 filtered out due to lack of AIS data.
Noon Report 32 filtered out due to lack of AIS data.
Noon Report 33 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 19

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
16	06-Sep-2016 11:00:00	07-Sep-2016 11:00:00	10.40	22.90 41.26	0.00 42.20	0.00 42.20
17	07-Sep-2016 11:00:00	08-Sep-2016 11:00:00	10.40	23.40 41.26	0.00 42.20	0.00 42.20
18	08-Sep-2016 11:00:00	09-Sep-2016 11:00:00	10.40	24.80 41.26	0.00 42.20	0.00 42.20
19	09-Sep-2016 11:00:00	10-Sep-2016 11:00:00	10.40	21.70 41.26	0.00 42.20	0.00 42.20
20	10-Sep-2016 11:00:00	11-Sep-2016 11:00:00	10.40	20.60 41.26	0.00 42.20	0.00 42.20

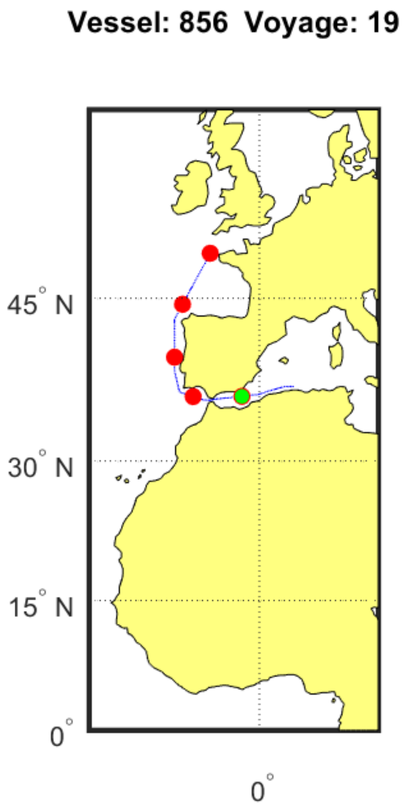
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
16	24	301	301	12.57	578.2	23.35	**
17	24	282	291	12.14	583.6	22.93	
18	24	273	277	11.57	560.3	20.88	
19	24	283	284	11.88	566.4	21.64	
20	24	279	279	11.69	564.5	21.23	

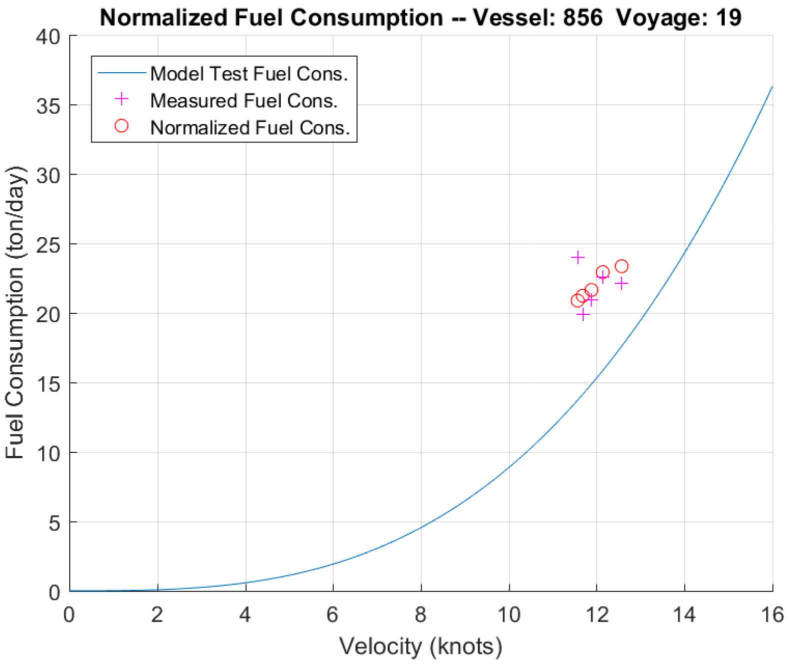
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 21 filtered out due to fuel use.
Noon Report 15 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 856; Voyage Name: 22

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
7	11-Nov-2016 11:00:00	12-Nov-2016 12:00:00	11.10	20.20 41.26	0.00 42.20	0.00 42.20
8	12-Nov-2016 12:00:00	13-Nov-2016 12:00:00	11.10	24.30 41.26	0.00 42.20	0.00 42.20
10	14-Nov-2016 13:00:00	15-Nov-2016 13:00:00	11.10	24.70 41.26	0.00 42.20	0.00 42.20
11	15-Nov-2016 13:00:00	16-Nov-2016 14:00:00	11.10	25.70 41.26	0.00 42.20	0.00 42.20
12	16-Nov-2016 14:00:00	17-Nov-2016 14:00:00	11.10	24.80 41.26	0.00 42.20	0.00 42.20
13	17-Nov-2016 14:00:00	18-Nov-2016 15:00:00	11.10	24.60 41.26	0.00 42.20	0.00 42.20
18	08-Dec-2016 17:00:00	09-Dec-2016 17:00:00	11.12	18.10 41.26	0.00 42.20	0.00 42.20
19	09-Dec-2016 17:00:00	10-Dec-2016 17:00:00	11.12	21.00 41.26	0.00 42.20	0.00 42.20
20	10-Dec-2016 17:00:00	11-Dec-2016 17:00:00	11.12	21.50 41.26	0.00 42.20	0.00 42.20
21	11-Dec-2016 17:00:00	12-Dec-2016 17:00:00	11.12	22.00 41.26	0.00 42.20	0.00 42.20
25	20-Dec-2016 17:00:00	21-Dec-2016 18:00:00	11.10	22.50 41.26	0.00 42.20	0.00 42.20

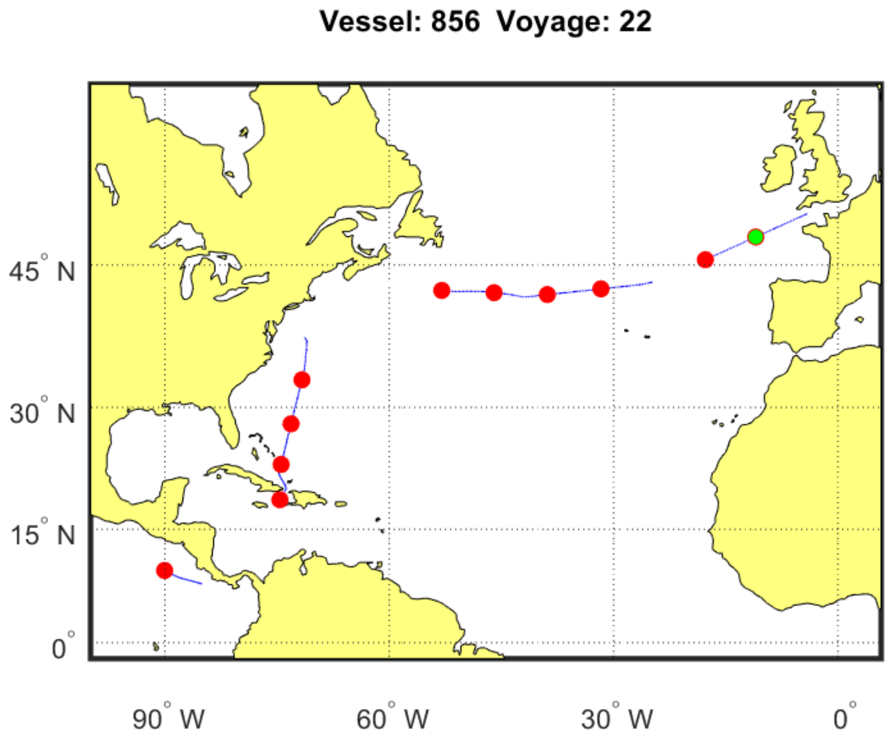
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
7	25	296	296	11.87	434.9	16.82	
8	24	304	303	12.65	436.5	17.74	
10	24	307	308	13.00	493.6	20.63	
11	25	315	323	12.98	505.9	21.12	
12	24	319	323	13.52	555.9	24.16	
13	25	310	315	12.65	562.3	23.02	
18	24	283	285	11.92	458.3	17.78	
19	24	311	304	12.68	528.7	21.53	
20	24	300	301	12.61	545.0	22.17	
21	24	289	285	11.91	586.7	22.60	
25	25	315	308	12.35	534.3	21.22	

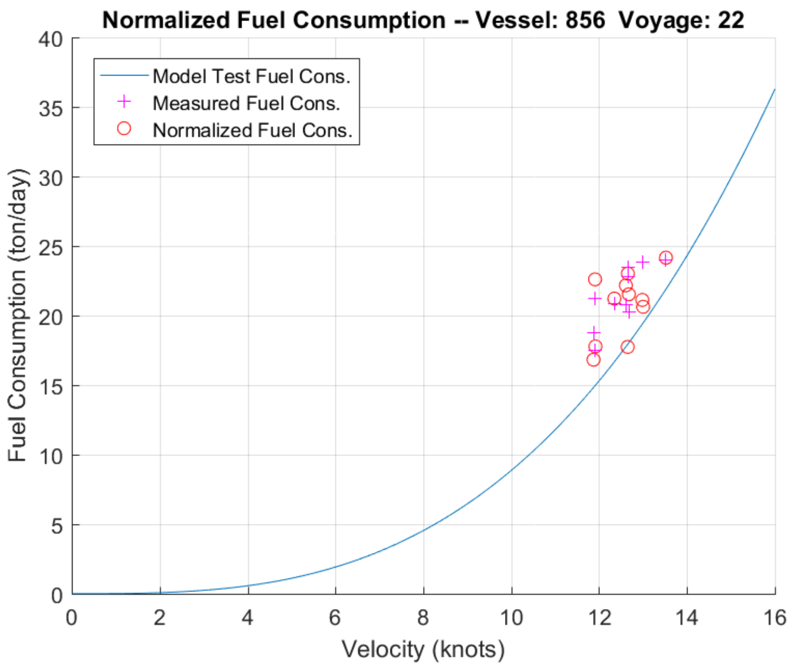
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to fuel use.
Noon Report 3 filtered out due to fuel use.
Noon Report 4 filtered out due to fuel use.
Noon Report 5 filtered out due to fuel use.
Noon Report 6 filtered out due to fuel use.
Noon Report 15 filtered out due to fuel use.
Noon Report 16 filtered out due to fuel use.
Noon Report 17 filtered out due to fuel use.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.
Noon Report 22 filtered out due to inconsistent AIS/NR lengths.
Noon Report 23 filtered out due to inconsistent AIS/NR lengths.
Noon Report 24 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1507

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
5	04-Jul-2015 17:00:00	05-Jul-2015 17:00:00	11.75	25.20 40.30	0.00 42.20	0.00 42.20
9	09-Jul-2015 17:00:00	10-Jul-2015 17:00:00	11.75	23.90 40.30	0.00 42.20	0.00 42.20
10	10-Jul-2015 17:00:00	11-Jul-2015 17:00:00	11.75	24.50 40.30	0.00 42.20	0.00 42.20
11	11-Jul-2015 17:00:00	12-Jul-2015 17:00:00	11.75	20.50 40.30	0.00 42.20	0.00 42.20
12	12-Jul-2015 17:00:00	12-Jul-2015 20:00:00	11.75	2.70 40.30	0.00 42.20	0.00 42.20

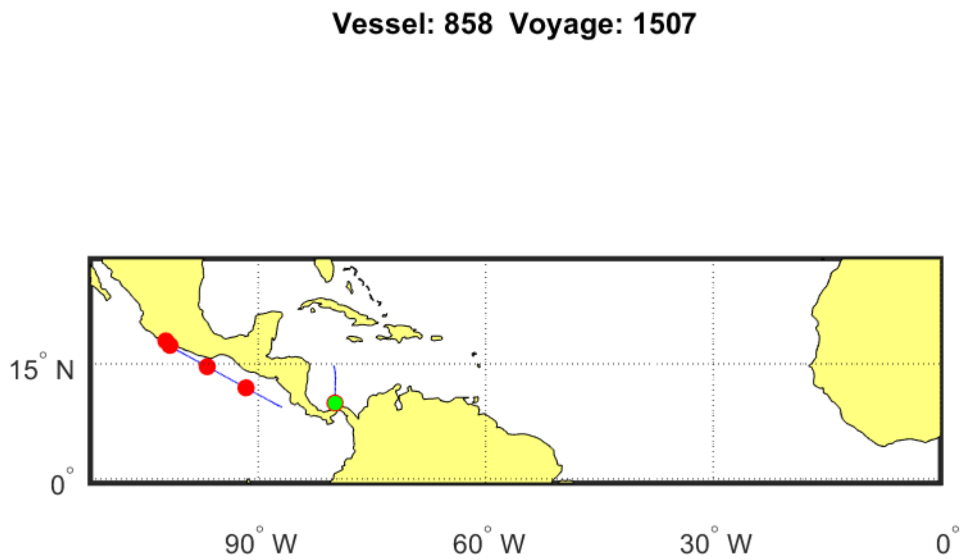
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
5	24	300	301	12.56	594.6	24.07	
9	24	332	314	13.11	533.6	22.53	
10	24	339	331	13.80	539.3	23.93	
11	24	325	302	12.62	496.2	20.21	
12	3	33	33	11.99	571.9	22.35	**

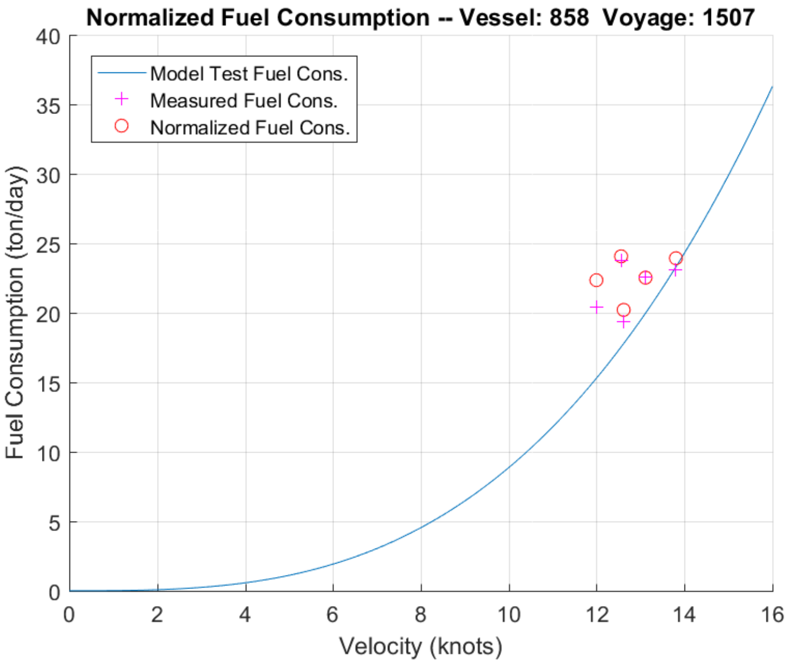
Filtered Data:

Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 16 filtered out due to draft.
Noon Report 17 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 20 filtered out due to draft.
Noon Report 21 filtered out due to draft.
Noon Report 22 filtered out due to draft.
Noon Report 23 filtered out due to draft.
Noon Report 24 filtered out due to draft.
Noon Report 6 filtered out manually.
Noon Report 1 filtered out due to inconsistent AIS/NR lengths.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1507.4

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
3	21-Aug-2015 19:00:00	22-Aug-2015 17:00:00	11.40	3.50 39.00	16.50 39.00	0.00 42.20
5	23-Aug-2015 17:00:00	24-Aug-2015 17:00:00	11.40	24.20 39.00	0.00 39.00	0.00 42.20
6	24-Aug-2015 17:00:00	25-Aug-2015 17:00:00	11.40	24.50 39.00	0.00 39.00	0.00 42.20
7	25-Aug-2015 17:00:00	26-Aug-2015 17:00:00	11.40	24.40 39.00	0.00 39.00	0.00 42.20
8	26-Aug-2015 17:00:00	27-Aug-2015 03:00:00	11.40	10.10 39.00	0.00 39.00	0.00 42.20

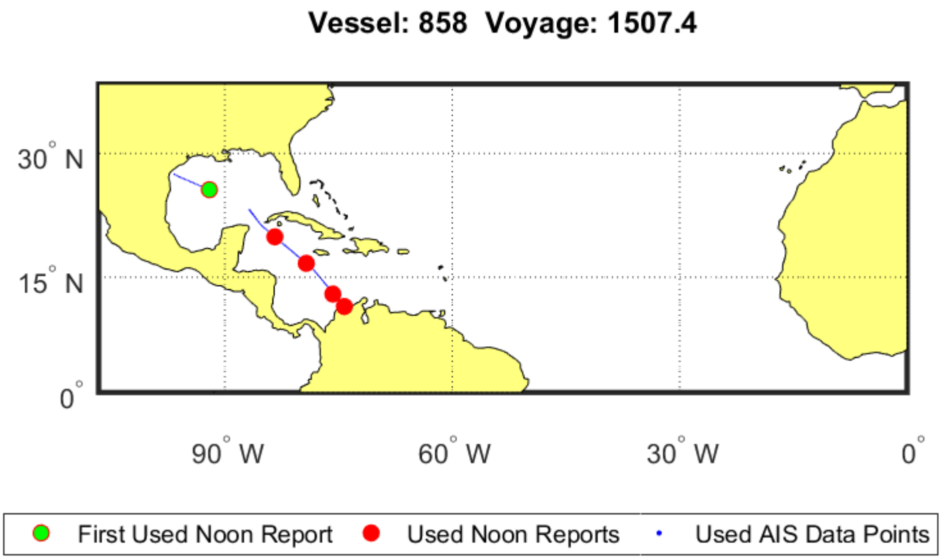
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
3	22	289	282	12.85	453.0	18.84	
5	24	291	313	13.05	520.1	22.01	
6	24	307	319	13.30	514.1	21.99	
7	24	309	314	13.11	513.1	21.62	
8	10	119	121	12.09	NaN	NaN	**

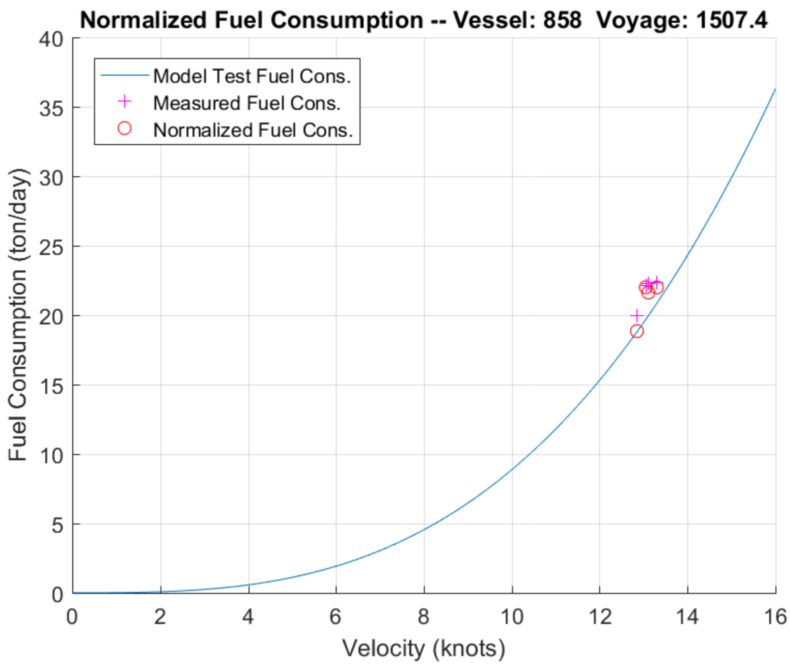
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1508.1

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
2	09-Sep-2015 17:00:00	10-Sep-2015 18:00:00	11.85	26.50 39.00	0.00 39.00	0.00 42.20
4	11-Sep-2015 18:00:00	12-Sep-2015 18:00:00	11.85	26.90 39.00	0.00 39.00	0.00 42.20
5	12-Sep-2015 18:00:00	13-Sep-2015 18:00:00	11.85	19.50 39.00	0.00 39.00	0.00 42.20

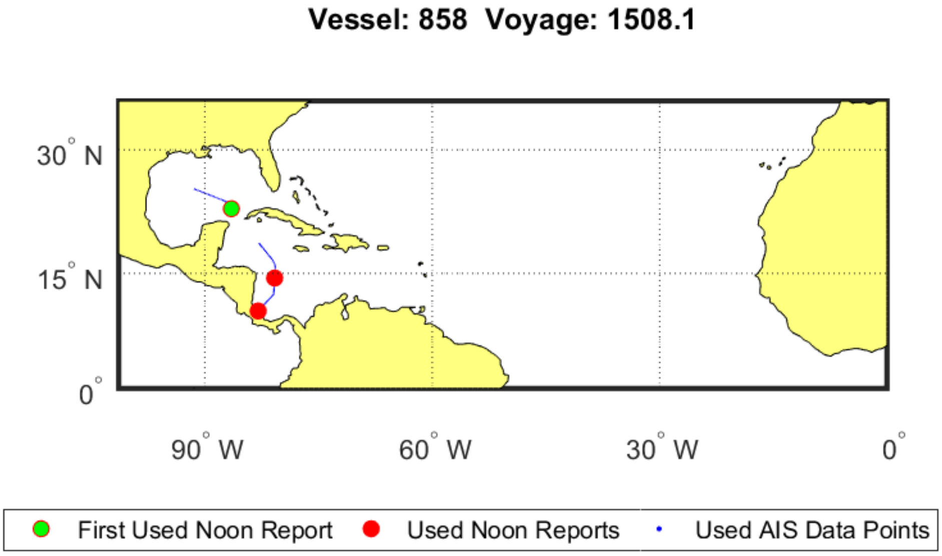
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
2	25	326	332	13.31	519.2	22.29	
4	24	310	308	12.98	563.6	23.52	
5	24	295	284	11.90	459.8	17.81	

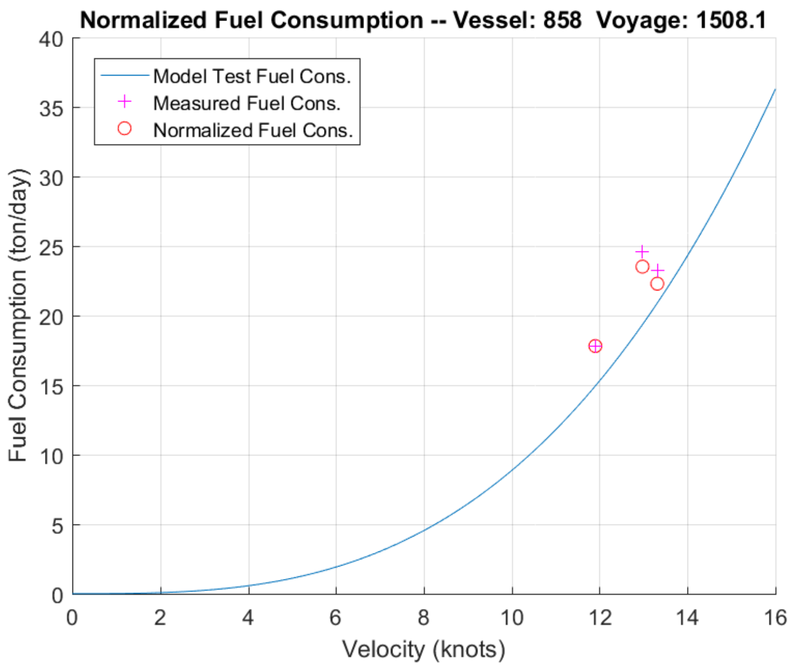
Filtered Data:

Noon Report 1 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1510.1

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
1	03-Oct-2015 03:00:00	03-Oct-2015 17:00:00	11.80	0.00 39.00	14.10 39.00	0.00 42.20
5	06-Oct-2015 17:00:00	07-Oct-2015 17:00:00	11.80	28.10 39.00	0.00 39.00	0.00 42.20
6	07-Oct-2015 17:00:00	08-Oct-2015 02:00:00	11.80	12.40 39.00	0.00 39.00	0.00 42.20

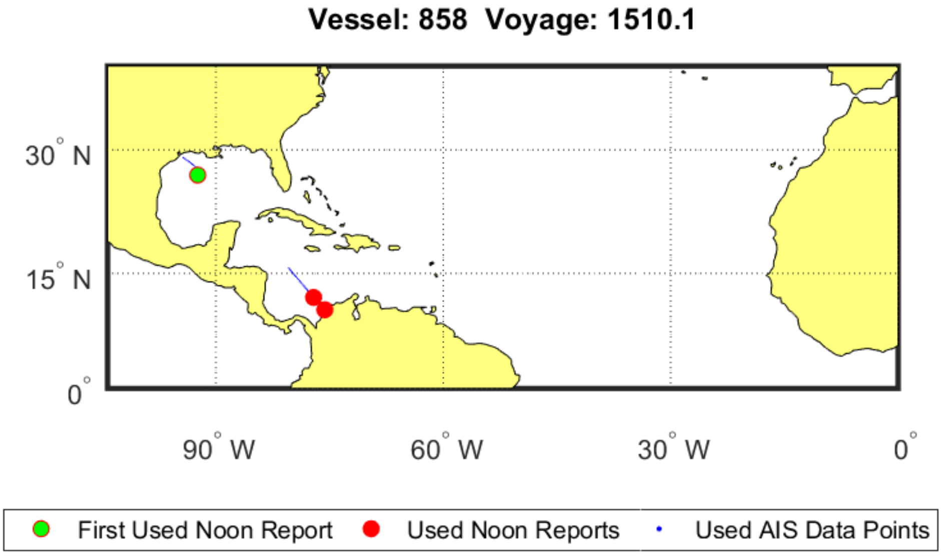
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
1	14	183	184	13.24	543.0	23.15	
5	24	312	333	13.93	541.2	24.28	
6	9	118	125	13.87	656.1	29.31	**

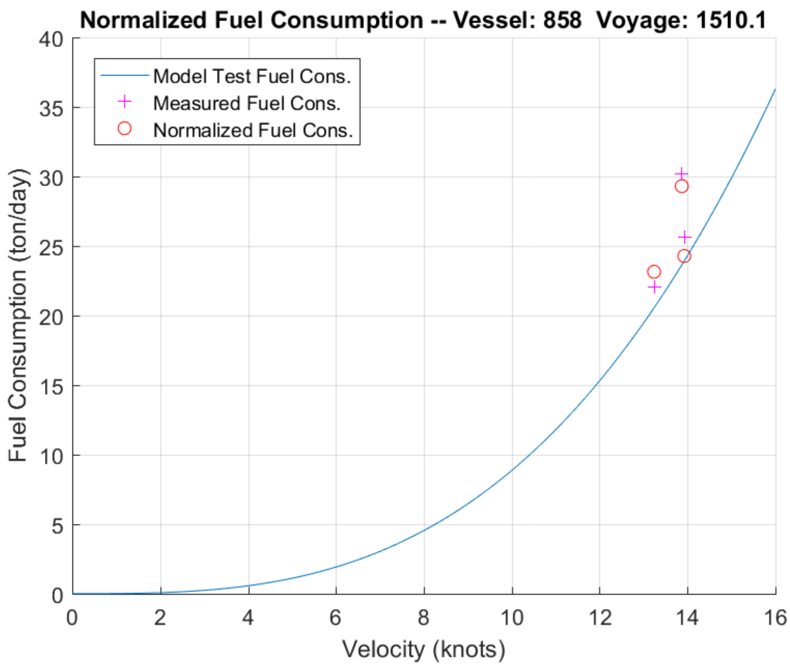
Filtered Data:

Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1511.1

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
2	27-Oct-2015 17:00:00	28-Oct-2015 17:00:00	10.60	17.70 39.00	6.00 39.00	0.00 42.20

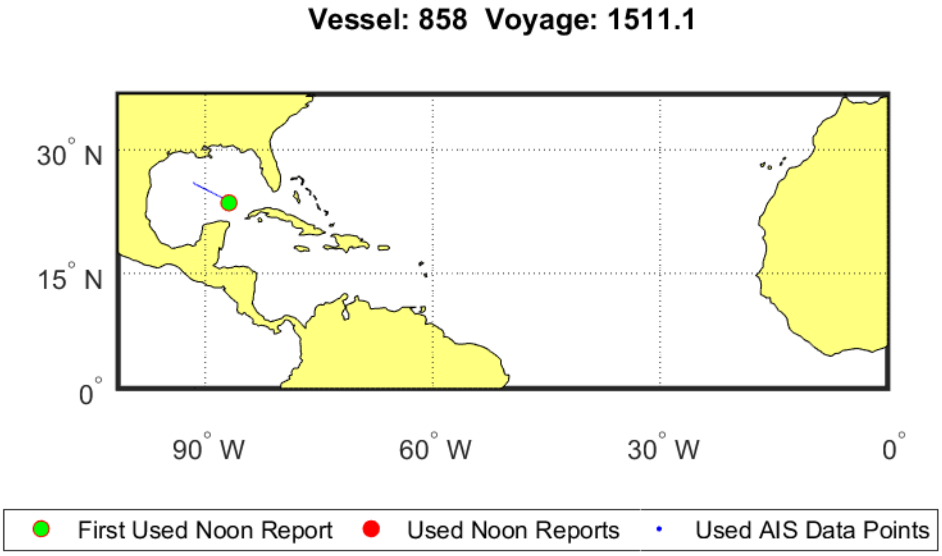
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
2	24	308	320	13.38	539.3	23.28	

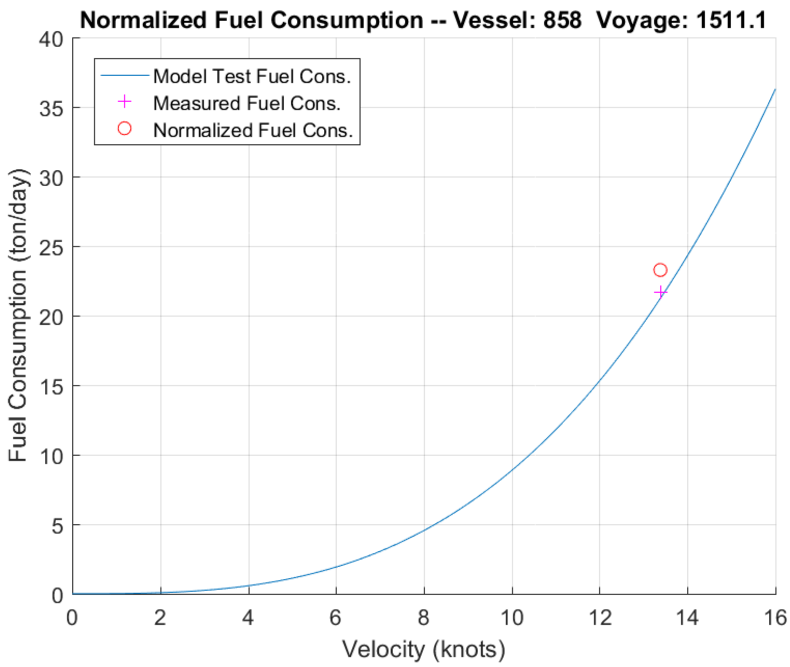
Filtered Data:

Noon Report 1 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 5 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1512.2

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
2	20-Nov-2015 18:00:00	21-Nov-2015 18:00:00	10.10	20.70 39.00	0.00 39.00	0.00 42.20

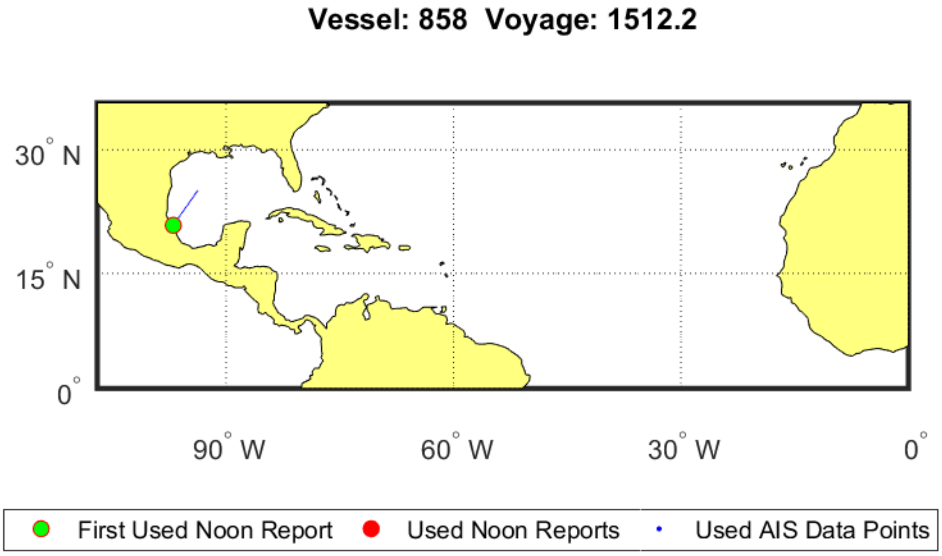
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
2	24	318	315	13.16	492.1	21.09	

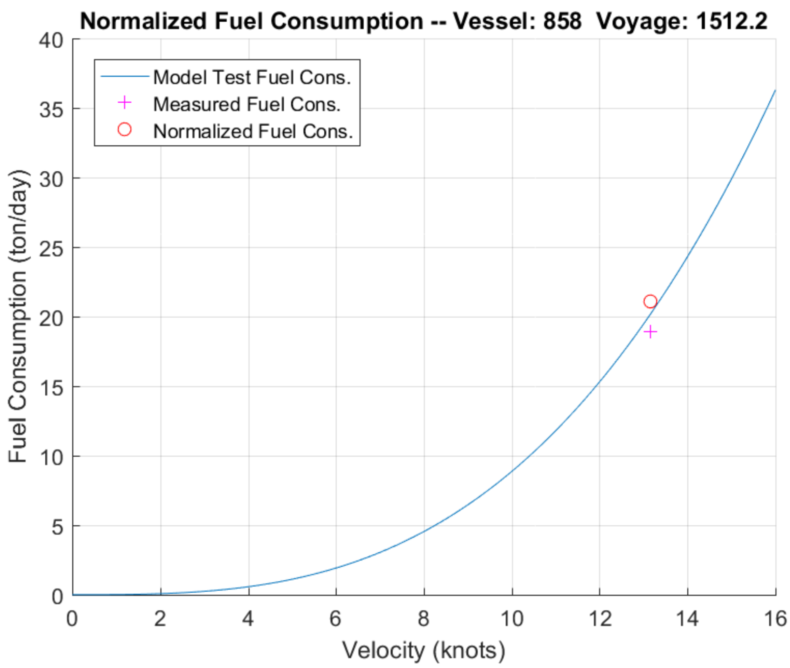
Filtered Data:

Noon Report 1 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1513.1

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10.rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
2	07-Dec-2015 18:00:00	08-Dec-2015 16:00:00	11.70	0.00 39.00	18.20 39.00	0.00 42.20

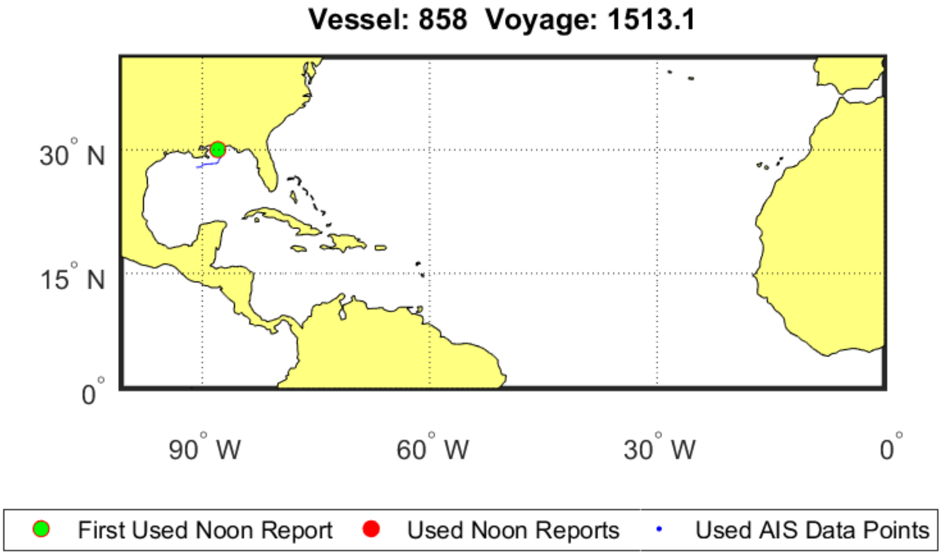
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
2	22	266	267	12.18	439.5	17.22	

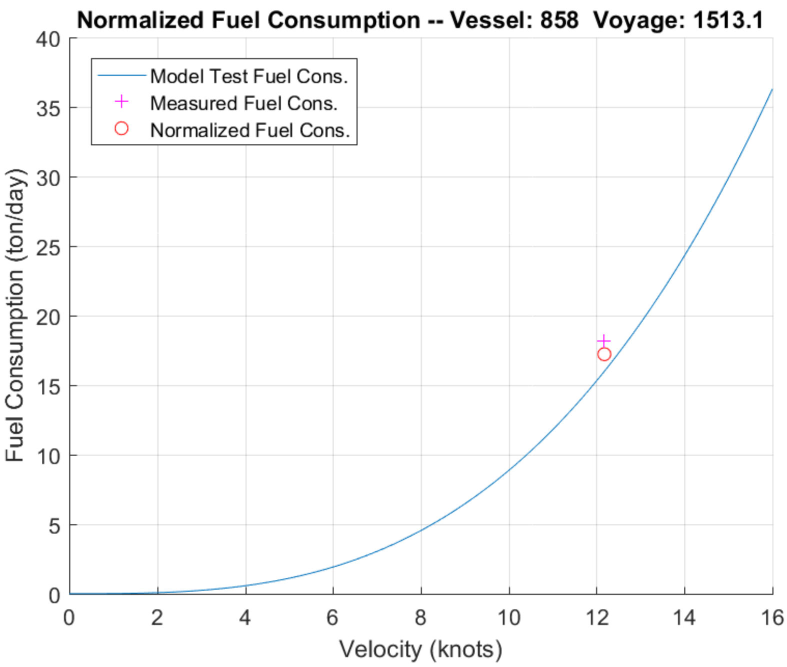
Filtered Data:

Noon Report 1 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 1513.4

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
4	16-Dec-2015 17:00:00	17-Dec-2015 17:00:00	10.25	22.60 39.00	0.00 39.00	0.00 42.20
5	18-Dec-2015 17:00:00	19-Dec-2015 16:00:00	10.25	22.30 39.00	0.00 39.00	0.00 42.20
7	20-Dec-2015 16:00:00	21-Dec-2015 16:00:00	10.25	23.60 39.00	0.00 39.00	0.00 42.20
8	21-Dec-2015 16:00:00	22-Dec-2015 16:00:00	10.25	22.40 39.00	0.00 39.00	0.00 42.20
10	23-Dec-2015 15:00:00	24-Dec-2015 15:00:00	10.25	23.20 39.00	0.00 39.00	0.00 42.20
12	25-Dec-2015 15:00:00	26-Dec-2015 15:00:00	10.25	23.00 39.00	0.00 39.00	0.00 42.20
14	27-Dec-2015 15:00:00	28-Dec-2015 15:00:00	10.25	21.10 39.00	0.00 39.00	0.00 42.20
15	28-Dec-2015 15:00:00	29-Dec-2015 15:00:00	10.25	21.30 39.00	0.00 39.00	0.00 42.20
16	29-Dec-2015 15:00:00	30-Dec-2015 15:00:00	10.25	22.20 39.00	0.00 39.00	0.00 42.20
18	31-Dec-2015 15:00:00	01-Jan-2016 12:00:00	10.25	20.40 39.00	0.00 39.00	0.00 42.20

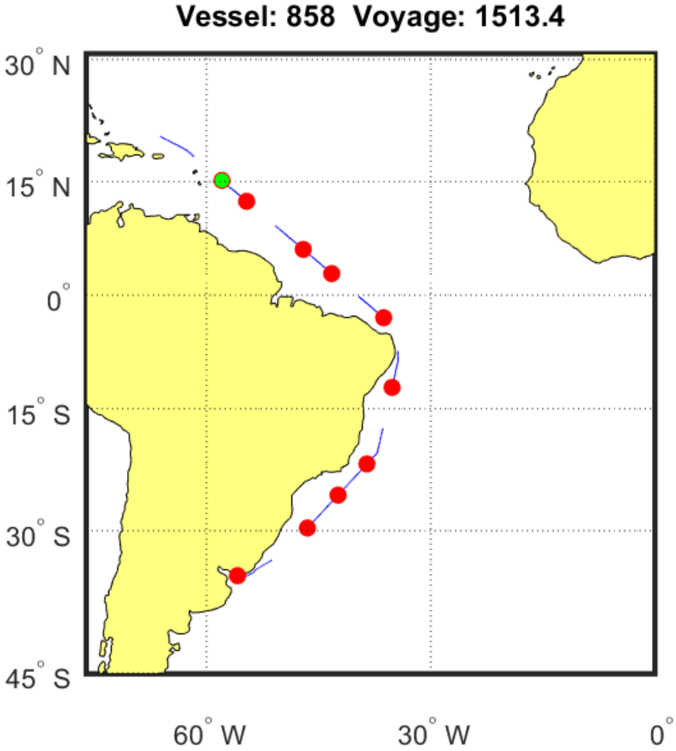
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
4	24	300	305	12.71	526.8	21.50	
5	23	262	271	11.79	417.3	15.86	
7	24	299	288	12.20	578.7	22.71	
8	24	294	298	12.45	531.6	21.30	
10	24	274	299	12.50	536.6	21.57	
12	24	303	303	12.66	548.0	22.28	
14	24	312	310	12.97	528.7	22.07	
15	24	310	311	13.00	536.7	22.45	
16	24	316	316	13.20	523.7	22.22	
18	21	266	265	12.66	560.3	23.09	**

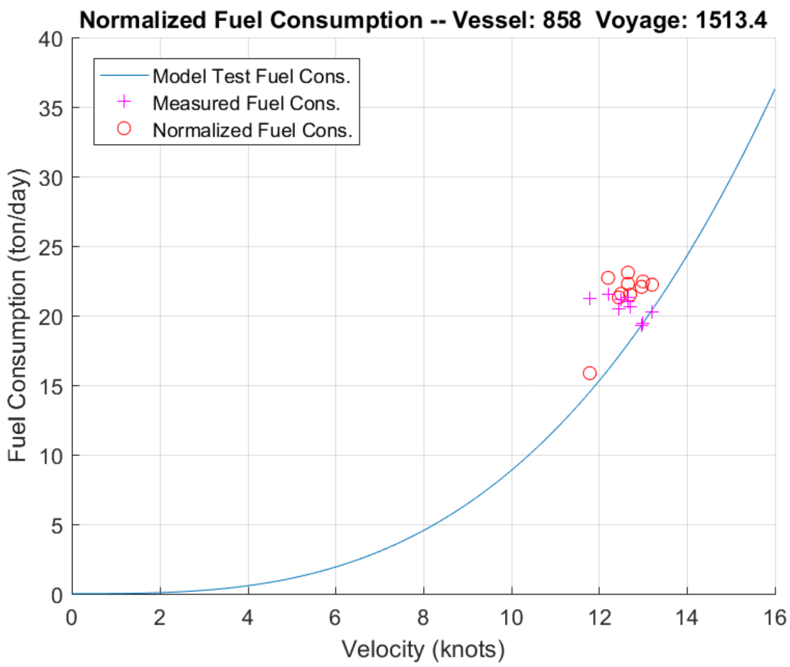
Filtered Data:

Noon Report 1 filtered out due to inconsistent AIS/NR lengths.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 17 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 3

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
1	23-Jul-2015 23:00:00	24-Jul-2015 18:00:00	9.40	17.80 39.00	0.00 39.00	0.00 42.20

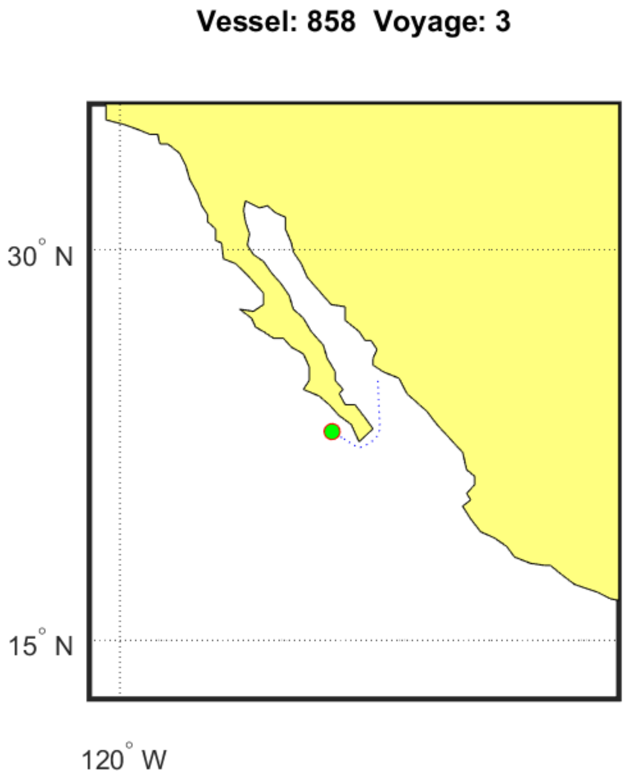
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
1	19	267	260	13.75	525.2	23.27	

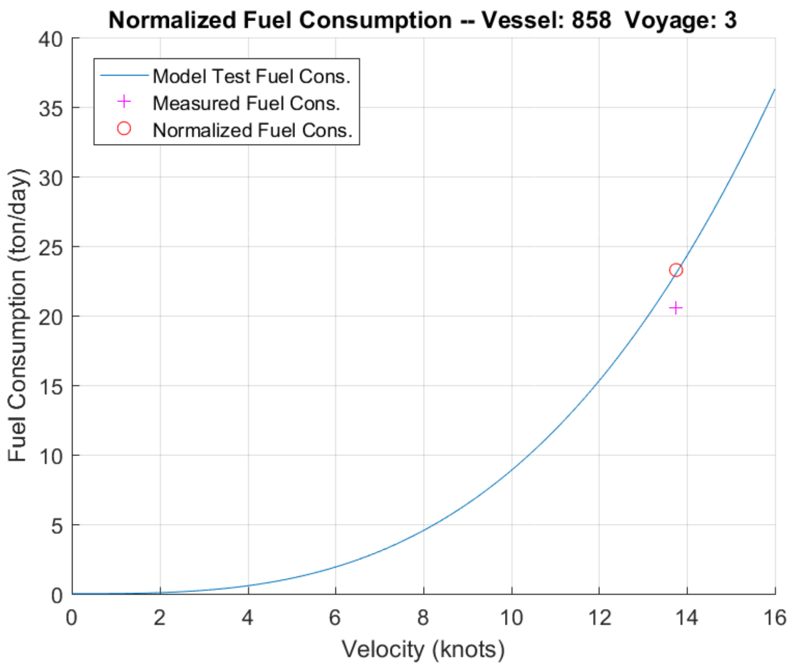
Filtered Data:

Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 858; Voyage Name: 18

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
12	19-Dec-2016 17:00:00	20-Dec-2016 17:00:00	9.90	22.50 39.00	0.00 42.56	0.00 42.20
13	20-Dec-2016 17:00:00	21-Dec-2016 17:00:00	9.90	23.50 39.00	0.00 42.56	0.00 42.20
14	21-Dec-2016 17:00:00	22-Dec-2016 16:00:00	9.90	22.00 39.00	0.00 42.56	0.00 42.20
16	23-Dec-2016 16:00:00	24-Dec-2016 16:00:00	9.90	22.60 39.00	0.00 42.56	0.00 42.20

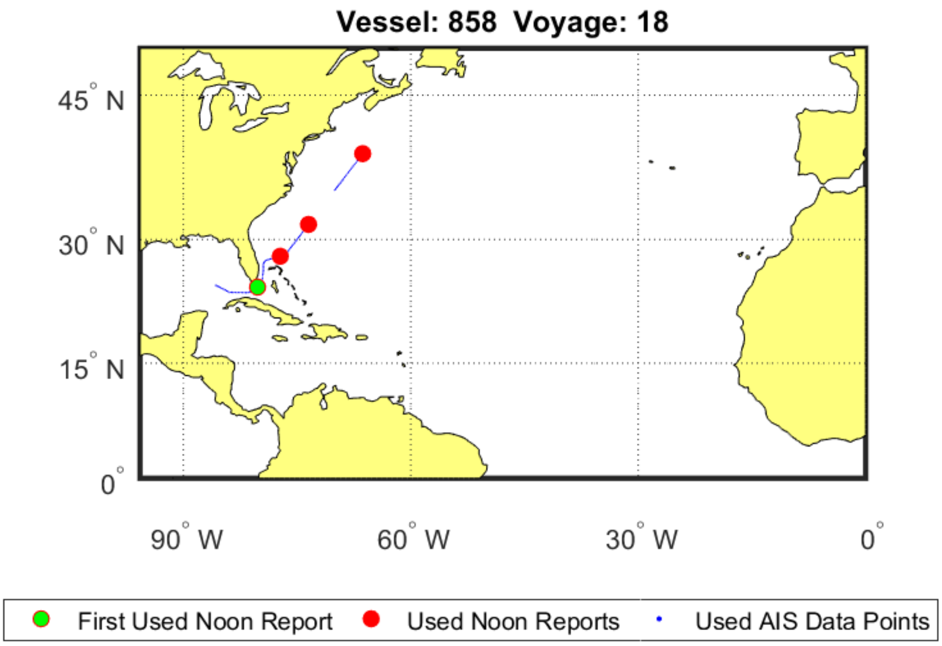
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
12	24	331	303	12.65	507.1	20.67	
13	24	314	284	11.83	557.2	21.38	
14	23	296	287	12.50	541.7	21.77	
16	24	292	277	11.57	599.1	22.43	

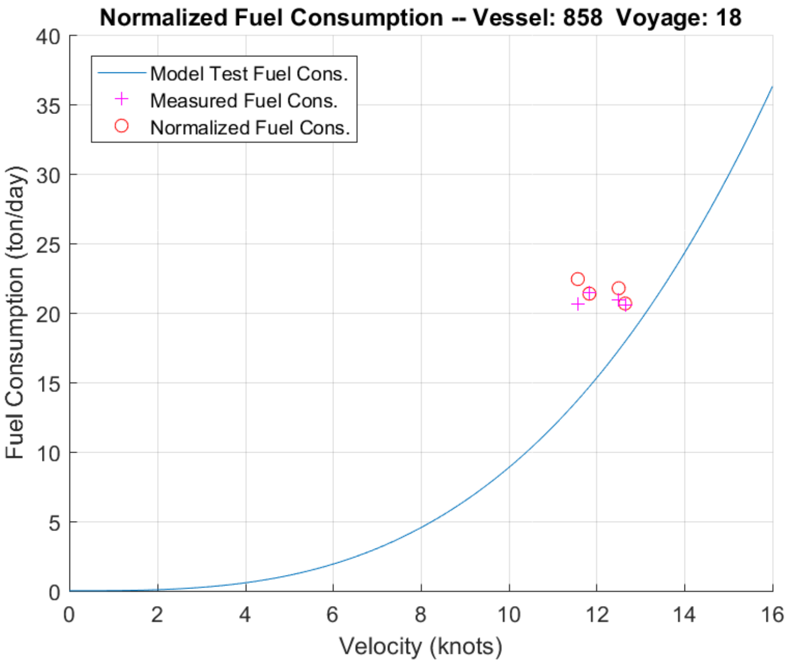
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.
Noon Report 15 filtered out due to inconsistent AIS/NR lengths.
Noon Report 17 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 019

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
5	15-Nov-2015 16:00:00	16-Nov-2015 16:00:00	9.50	24.70 40.30	0.00 42.20	0.00 42.20
6	16-Nov-2015 16:00:00	17-Nov-2015 16:00:00	9.50	22.70 40.30	0.00 42.20	0.00 42.20
7	17-Nov-2015 16:00:00	18-Nov-2015 15:00:00	9.50	22.70 40.30	0.00 42.20	0.00 42.20
8	18-Nov-2015 15:00:00	19-Nov-2015 15:00:00	9.50	20.70 40.30	0.00 42.20	0.00 42.20
9	19-Nov-2015 15:00:00	20-Nov-2015 15:00:00	9.50	20.10 40.30	0.00 42.20	0.00 42.20
11	21-Nov-2015 15:00:00	22-Nov-2015 15:00:00	9.50	20.50 40.30	0.00 42.20	0.00 42.20
12	22-Nov-2015 15:00:00	23-Nov-2015 15:00:00	9.50	20.60 40.30	0.00 42.20	0.00 42.20
13	23-Nov-2015 15:00:00	24-Nov-2015 15:00:00	9.50	20.50 40.30	0.00 42.20	0.00 42.20
14	24-Nov-2015 15:00:00	25-Nov-2015 15:00:00	9.50	20.50 40.30	0.00 42.20	0.00 42.20
15	25-Nov-2015 15:00:00	26-Nov-2015 15:00:00	9.50	21.20 40.30	0.00 42.20	0.00 42.20
17	27-Nov-2015 15:00:00	28-Nov-2015 15:00:00	9.50	25.60 40.30	0.00 42.20	0.00 42.20
18	28-Nov-2015 15:00:00	29-Nov-2015 15:00:00	9.50	26.70 40.30	0.00 42.20	0.00 42.20
19	29-Nov-2015 15:00:00	30-Nov-2015 15:00:00	9.50	25.60 40.30	0.00 42.20	0.00 42.20

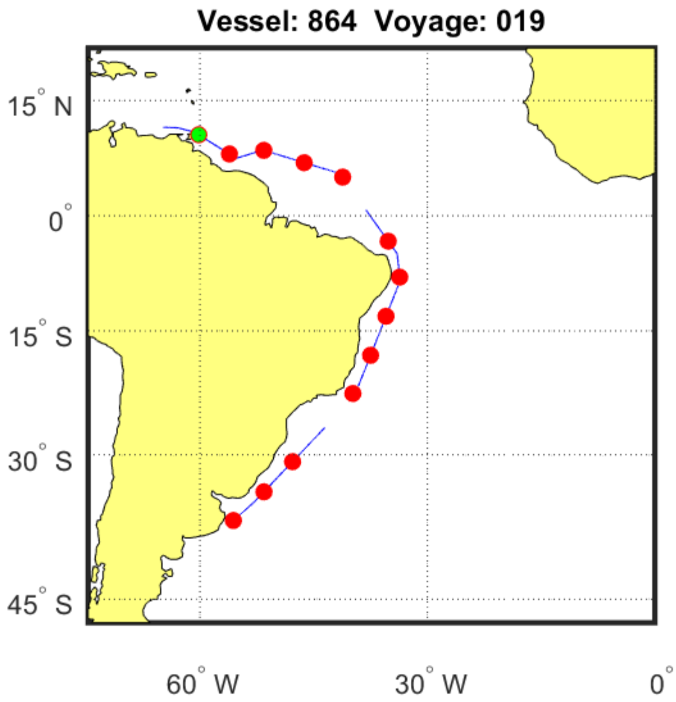
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
5	24	286	301	12.59	557.3	22.59	
6	24	281	290	12.14	544.3	22.83	
7	23	286	297	12.97	466.7	19.46	
8	24	331	314	13.11	432.9	18.29	
9	24	329	305	12.71	408.2	17.26	
11	24	303	312	13.03	488.1	20.46	
12	24	303	305	12.75	446.1	18.28	
13	24	323	315	13.14	524.1	22.14	
14	24	316	311	13.00	504.8	21.12	
15	24	310	302	12.66	532.6	21.67	
17	24	326	321	13.41	651.9	28.09	
18	24	275	271	11.34	662.0	24.87	
19	24	268	286	11.95	585.8	22.58	

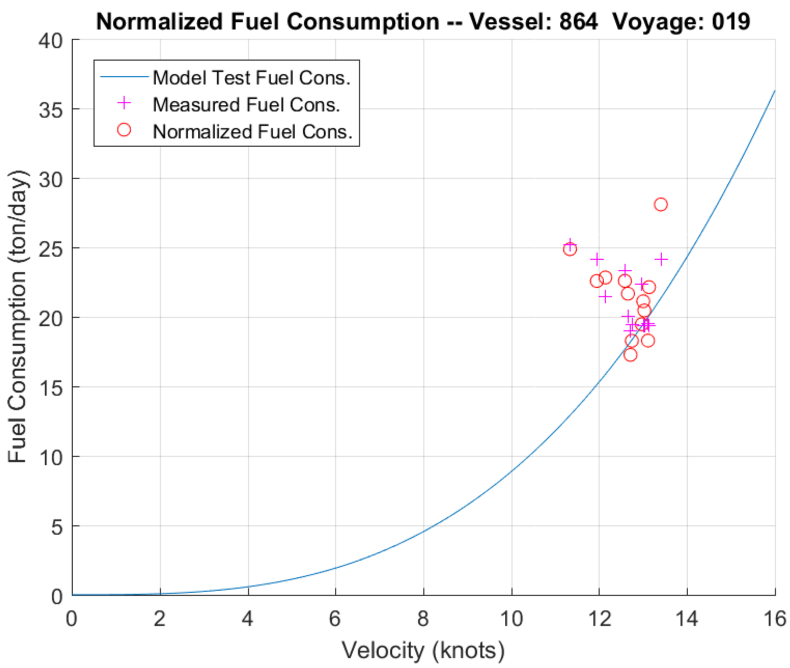
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 10 filtered out due to inconsistent AIS/NR lengths.
Noon Report 16 filtered out due to inconsistent AIS/NR lengths.
Noon Report 20 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 19

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
3	07-Dec-2015 14:00:00	08-Dec-2015 14:00:00	10.70	25.60 42.35	0.00 42.20	0.00 42.20
4	08-Dec-2015 14:00:00	09-Dec-2015 14:00:00	10.70	27.10 42.35	0.00 42.20	0.00 42.20

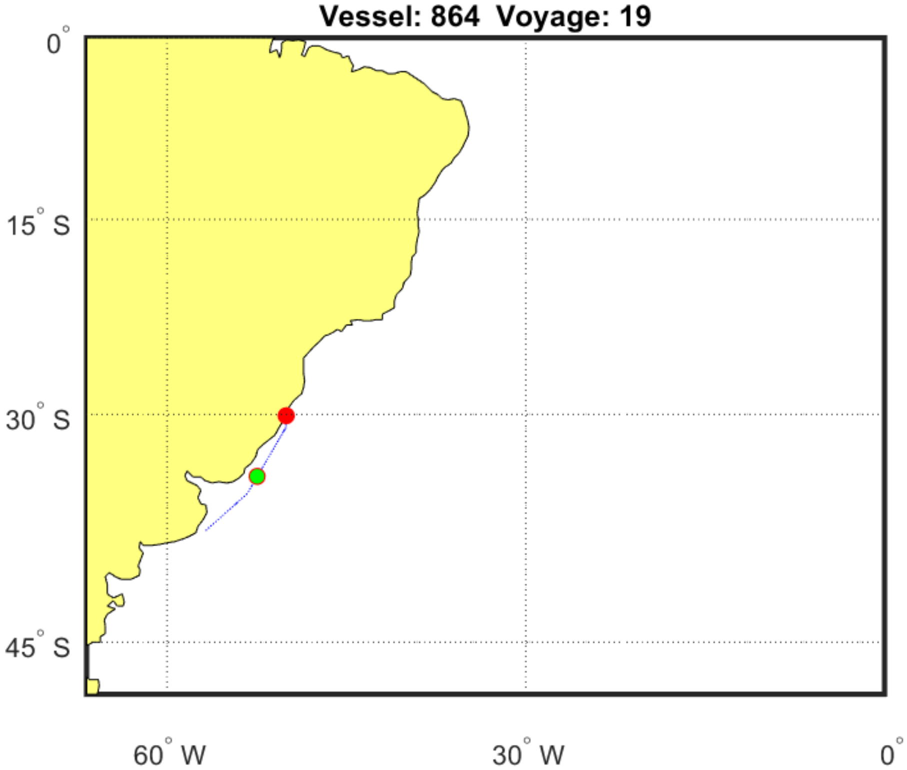
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
3	24	307	304	12.73	634.0	25.95	
4	24	289	293	12.24	680.3	26.86	

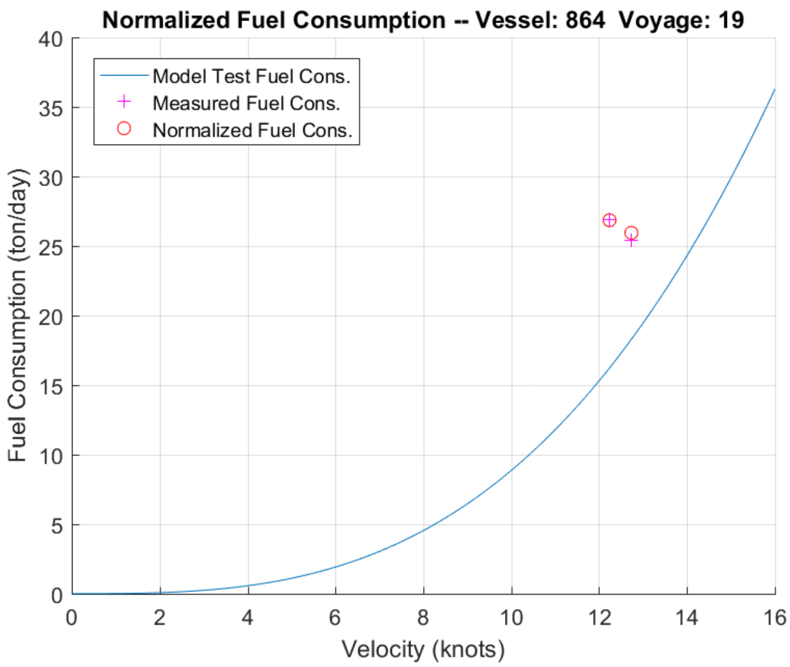
Filtered Data:

Noon Report 1 filtered out due to inconsistent AIS/NR lengths.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 25

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
3	23-May-2016 05:00:00	23-May-2016 17:00:00	12.50	0.00 40.43	0.00 42.20	13.20 42.43
4	23-May-2016 17:00:00	24-May-2016 17:00:00	12.50	20.90 40.43	0.00 42.20	3.10 42.43
5	24-May-2016 17:00:00	25-May-2016 16:00:00	12.50	29.50 40.43	0.00 42.20	0.00 42.43
6	25-May-2016 16:00:00	26-May-2016 16:00:00	12.50	31.10 40.43	0.00 42.20	0.00 42.43
7	26-May-2016 16:00:00	27-May-2016 15:00:00	12.50	29.70 40.43	0.00 42.20	0.00 42.43
8	27-May-2016 15:00:00	28-May-2016 15:00:00	12.50	30.20 40.43	0.00 42.20	0.00 42.43
9	29-May-2016 14:00:00	30-May-2016 14:00:00	12.50	31.80 40.43	0.00 42.20	0.00 42.43
10	30-May-2016 14:00:00	31-May-2016 13:00:00	12.50	29.30 40.43	0.00 42.20	0.00 42.43
11	31-May-2016 13:00:00	01-Jun-2016 13:00:00	12.50	29.90 40.43	0.00 42.20	0.00 42.43
14	03-Jun-2016 12:00:00	04-Jun-2016 11:00:00	12.50	27.70 40.43	0.00 42.20	0.00 42.43
15	04-Jun-2016 11:00:00	05-Jun-2016 11:00:00	12.50	29.90 40.43	0.00 42.20	0.00 42.43
16	05-Jun-2016 11:00:00	06-Jun-2016 10:00:00	12.50	24.70 40.43	0.00 42.20	2.90 42.43

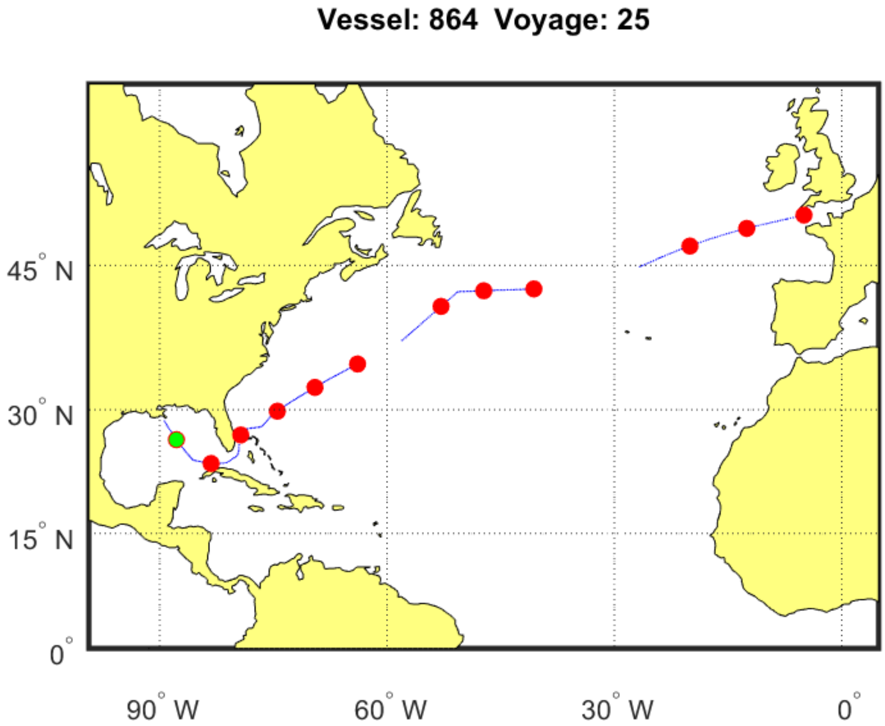
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
3	12	160	162	13.48	556.4	24.11	
4	24	321	322	13.46	476.3	20.77	
5	23	353	317	13.80	605.5	26.94	
6	24	330	316	13.20	617.3	26.25	
7	23	300	302	13.13	627.4	26.50	
8	24	319	322	13.41	607.7	26.18	
9	24	323	295	12.30	620.2	24.95	
10	23	282	284	12.36	536.8	21.37	
11	24	291	295	12.32	649.1	25.76	
14	23	305	305	13.28	570.0	24.94	
15	24	318	318	13.27	597.6	25.52	
16	23	305	303	13.20	581.2	24.84	

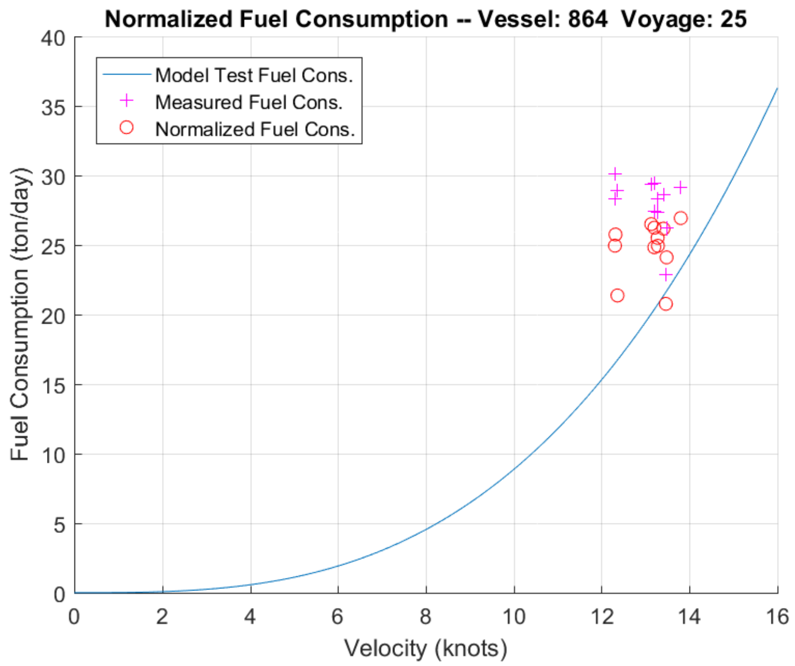
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 12 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 17 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 26

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
4	22-Jun-2016 09:00:00	23-Jun-2016 10:00:00	11.05	0.10 40.43	0.00 42.20	21.50 42.43
5	23-Jun-2016 10:00:00	24-Jun-2016 11:00:00	11.40	19.60 40.43	0.00 42.20	7.80 42.43
7	25-Jun-2016 11:00:00	26-Jun-2016 12:00:00	11.40	32.30 40.43	0.00 42.20	0.00 42.43
8	26-Jun-2016 12:00:00	27-Jun-2016 12:00:00	11.40	31.00 40.43	0.00 42.20	0.00 42.43
10	28-Jun-2016 13:00:00	29-Jun-2016 13:00:00	11.40	30.70 40.43	0.00 42.20	0.00 42.43
11	29-Jun-2016 13:00:00	30-Jun-2016 14:00:00	11.40	33.10 40.43	0.00 42.20	0.00 42.43
12	30-Jun-2016 14:00:00	01-Jul-2016 14:00:00	11.40	31.00 40.43	0.00 42.20	0.00 42.43
13	01-Jul-2016 14:00:00	02-Jul-2016 15:00:00	11.40	32.90 40.43	0.00 42.20	0.00 42.43
14	02-Jul-2016 15:00:00	03-Jul-2016 15:00:00	11.40	31.20 40.43	0.00 42.20	0.00 42.43
15	03-Jul-2016 15:00:00	04-Jul-2016 16:00:00	11.40	33.20 40.43	0.00 42.20	0.00 42.43
16	04-Jul-2016 16:00:00	05-Jul-2016 17:00:00	11.40	31.70 40.43	0.00 42.20	0.00 42.43
17	05-Jul-2016 17:00:00	06-Jul-2016 02:00:00	11.40	11.40 40.43	0.00 42.20	0.00 42.43

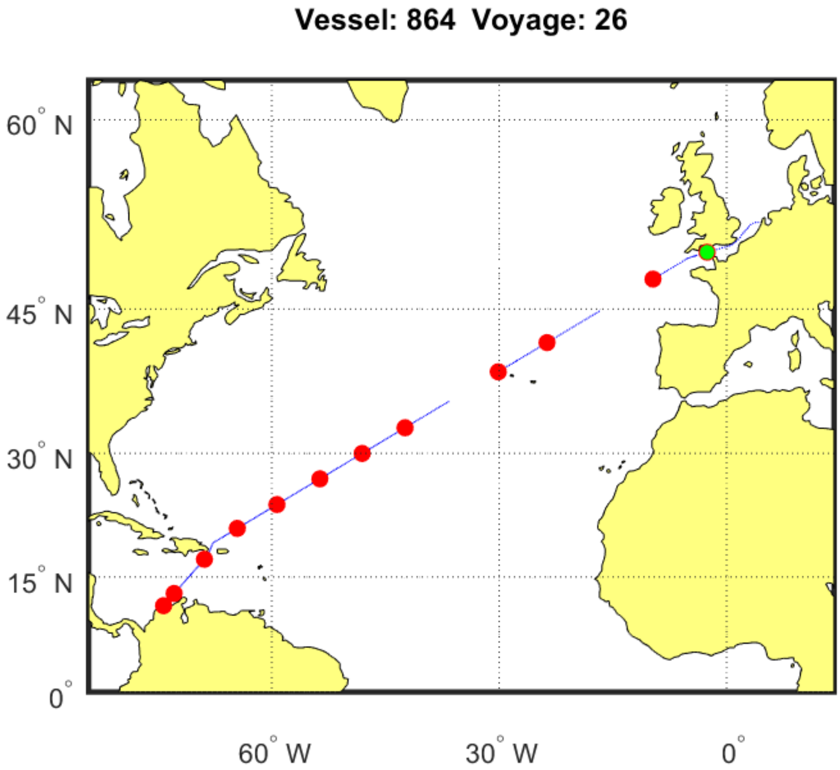
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
4	25	318	321	12.88	NaN	NaN	**
5	25	314	313	12.57	583.9	24.17	
7	25	356	354	14.19	639.2	29.17	
8	24	342	343	14.28	627.5	28.79	
10	24	337	337	14.07	635.7	29.19	
11	25	337	344	13.81	670.7	31.34	
12	24	342	340	14.20	660.8	30.16	
13	25	356	357	14.32	669.9	30.82	
14	24	337	338	14.09	671.5	30.40	
15	25	349	352	14.14	682.3	31.02	
16	25	347	349	13.96	680.4	30.66	
17	9	119	117	12.96	736.6	31.20	

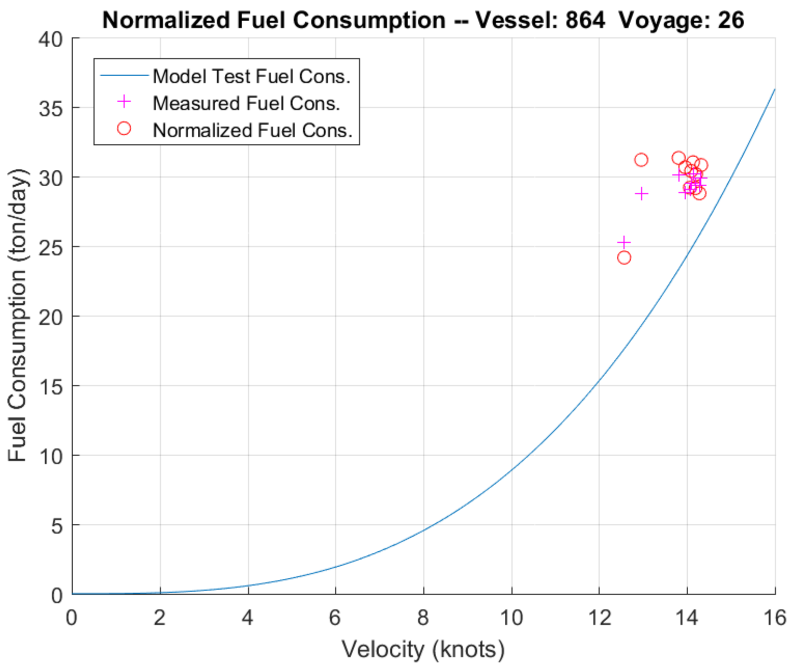
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 18 filtered out due to draft.
Noon Report 19 filtered out due to draft.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 27

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
9	23-Jul-2016 16:00:00	24-Jul-2016 16:00:00	12.10	28.90 40.43	0.00 42.20	0.00 42.43
11	25-Jul-2016 15:00:00	26-Jul-2016 15:00:00	12.10	29.10 40.43	0.00 42.20	0.00 42.43
12	26-Jul-2016 15:00:00	27-Jul-2016 14:00:00	12.10	28.10 40.43	0.00 42.20	0.00 42.43
13	27-Jul-2016 14:00:00	28-Jul-2016 14:00:00	12.10	29.40 40.43	0.00 42.20	0.00 42.43
14	28-Jul-2016 14:00:00	29-Jul-2016 13:00:00	12.10	28.20 40.43	0.00 42.20	0.00 42.43
15	29-Jul-2016 13:00:00	30-Jul-2016 13:00:00	12.10	29.00 40.43	0.00 42.20	0.00 42.43
17	31-Jul-2016 12:00:00	01-Aug-2016 12:00:00	12.10	29.70 40.43	0.00 42.20	0.00 42.43
18	01-Aug-2016 12:00:00	02-Aug-2016 11:00:00	12.10	28.50 40.43	0.00 42.20	0.00 42.43
20	03-Aug-2016 11:00:00	04-Aug-2016 10:00:00	12.10	28.20 40.43	0.00 42.20	0.00 42.43
21	04-Aug-2016 10:00:00	05-Aug-2016 10:00:00	12.10	0.00 40.43	0.00 42.20	20.90 42.43

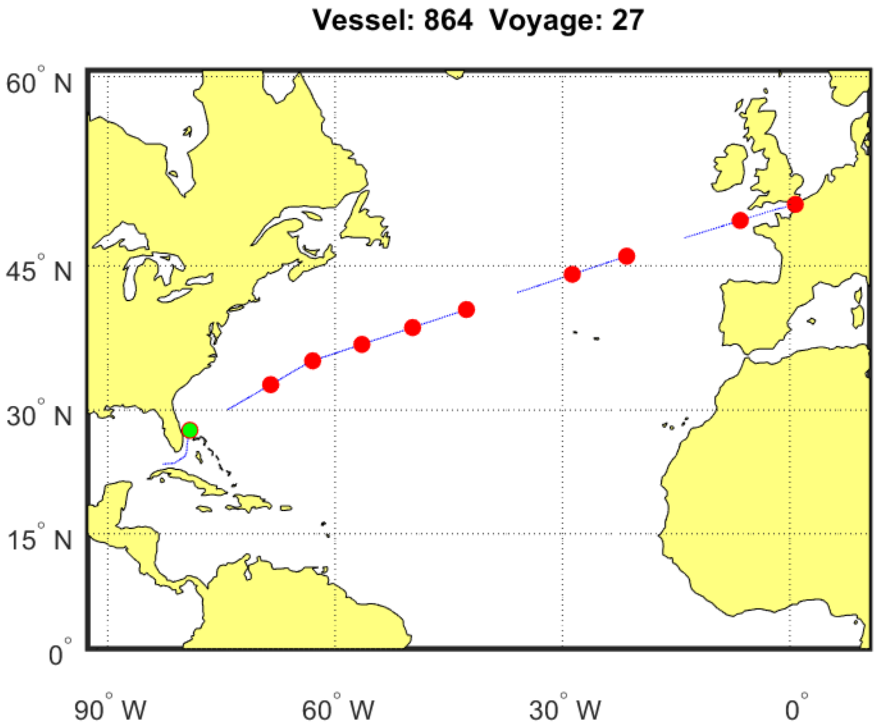
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
9	24	372	332	13.87	579.0	25.94	
11	24	335	336	13.99	586.1	26.36	
12	23	314	316	13.82	616.6	27.39	
13	24	329	326	13.65	630.3	27.77	
14	23	332	309	13.46	640.3	27.86	
15	24	344	335	13.98	592.0	26.94	
17	24	336	328	13.69	633.8	27.89	
18	23	321	311	13.52	663.0	28.81	
20	23	310	310	13.48	634.9	27.57	
21	24	294	292	12.21	500.5	22.55	

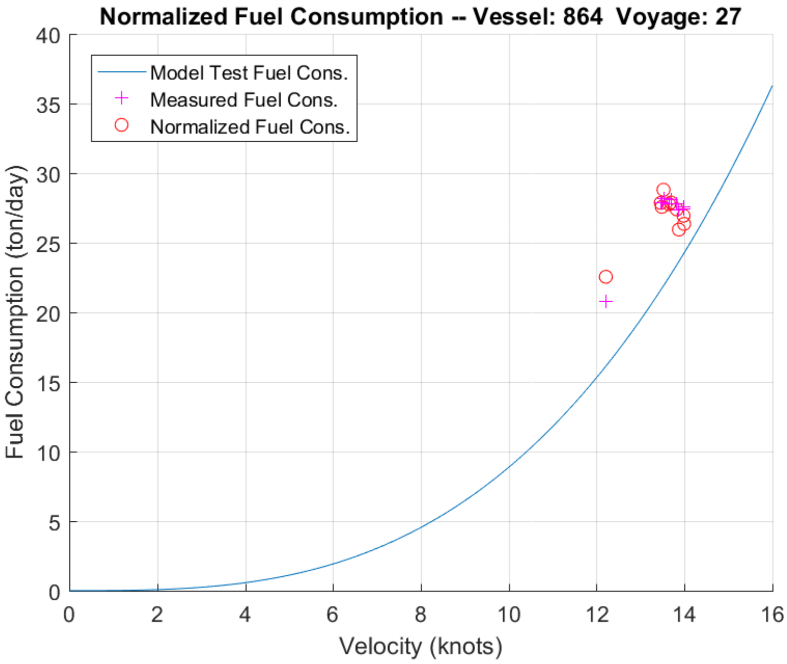
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.
Noon Report 10 filtered out due to inconsistent AIS/NR lengths.
Noon Report 16 filtered out due to inconsistent AIS/NR lengths.
Noon Report 19 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 28

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
2	18-Aug-2016 11:00:00	19-Aug-2016 11:00:00	10.40	5.60 40.43	0.00 42.20	21.90 42.43
3	19-Aug-2016 11:00:00	20-Aug-2016 11:00:00	10.40	31.10 40.43	0.00 42.20	0.00 42.43
6	22-Aug-2016 12:00:00	23-Aug-2016 13:00:00	10.40	32.90 40.43	0.00 42.20	0.00 42.43
7	23-Aug-2016 13:00:00	24-Aug-2016 13:00:00	10.40	26.10 40.43	0.00 42.20	0.00 42.43
8	24-Aug-2016 13:00:00	25-Aug-2016 14:00:00	10.40	28.90 40.43	0.00 42.20	0.00 42.43
9	25-Aug-2016 14:00:00	26-Aug-2016 14:00:00	10.40	26.80 40.43	0.00 42.20	0.00 42.43
10	26-Aug-2016 14:00:00	27-Aug-2016 15:00:00	10.40	28.20 40.43	0.00 42.20	0.00 42.43
11	27-Aug-2016 15:00:00	28-Aug-2016 15:00:00	10.40	25.80 40.43	0.00 42.20	0.00 42.43
12	28-Aug-2016 15:00:00	29-Aug-2016 15:00:00	10.40	25.80 40.43	0.00 42.20	0.00 42.43
13	29-Aug-2016 15:00:00	30-Aug-2016 16:00:00	10.40	27.80 40.43	0.00 42.20	0.00 42.43
15	31-Aug-2016 16:00:00	01-Sep-2016 16:00:00	10.40	27.10 40.43	0.00 42.20	0.00 42.43
16	01-Sep-2016 16:00:00	02-Sep-2016 17:00:00	10.40	28.00 40.43	0.00 42.20	0.00 42.43
18	03-Sep-2016 17:00:00	04-Sep-2016 17:00:00	10.40	25.60 40.43	0.00 42.20	0.00 42.43

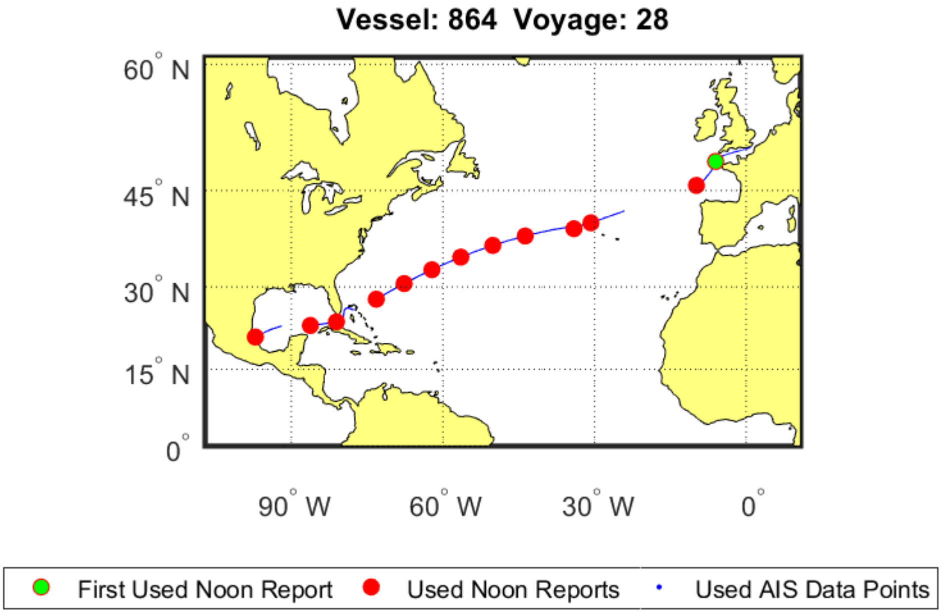
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
2	24	295	298	12.43	630.4	26.37	
3	24	256	258	10.75	831.2	29.02	
6	25	316	315	12.61	743.0	32.12	
7	24	302	307	12.82	621.3	25.94	
8	25	316	316	12.69	644.0	26.27	
9	24	317	313	13.09	591.8	24.99	
10	25	326	319	12.79	650.8	26.78	
11	24	310	308	12.86	625.8	25.86	
12	24	311	311	13.01	624.0	26.08	
13	25	330	331	13.25	628.7	26.77	
15	24	276	316	13.21	630.1	26.79	
16	25	287	314	12.57	629.2	25.68	
18	24	315	313	13.08	617.7	26.30	

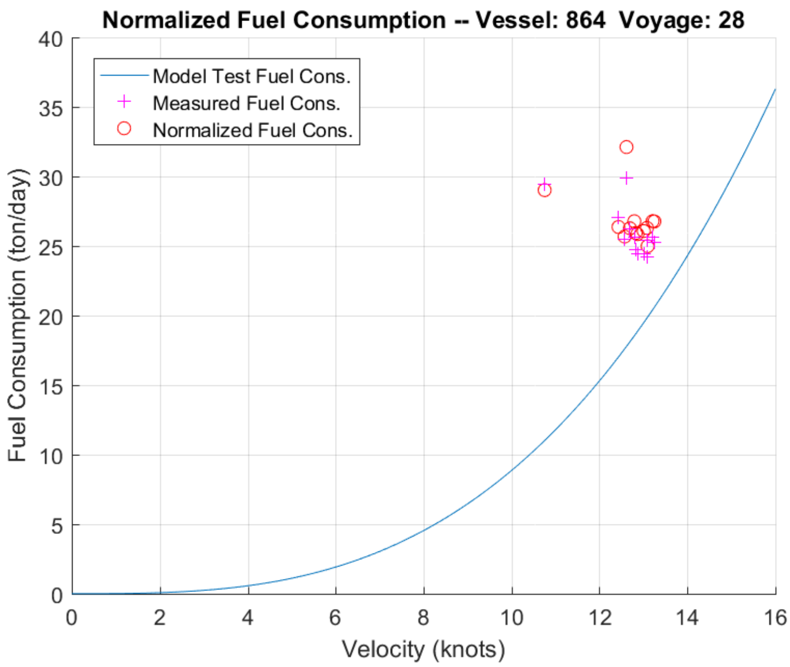
Filtered Data:

Noon Report 1 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 5 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.
Noon Report 17 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 29

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
7	20-Sep-2016 15:00:00	20-Sep-2016 17:00:00	11.34	2.20 40.43	0.00 42.20	0.00 42.43
9	21-Sep-2016 17:00:00	22-Sep-2016 17:00:00	11.70	33.00 40.43	0.00 42.20	0.00 42.43
10	22-Sep-2016 17:00:00	23-Sep-2016 17:00:00	11.70	33.20 40.43	0.00 42.20	0.20 42.43
11	23-Sep-2016 17:00:00	24-Sep-2016 17:00:00	11.70	33.30 40.43	0.00 42.20	0.20 42.43
12	24-Sep-2016 17:00:00	25-Sep-2016 17:00:00	11.70	33.10 40.43	0.00 42.20	0.00 42.43

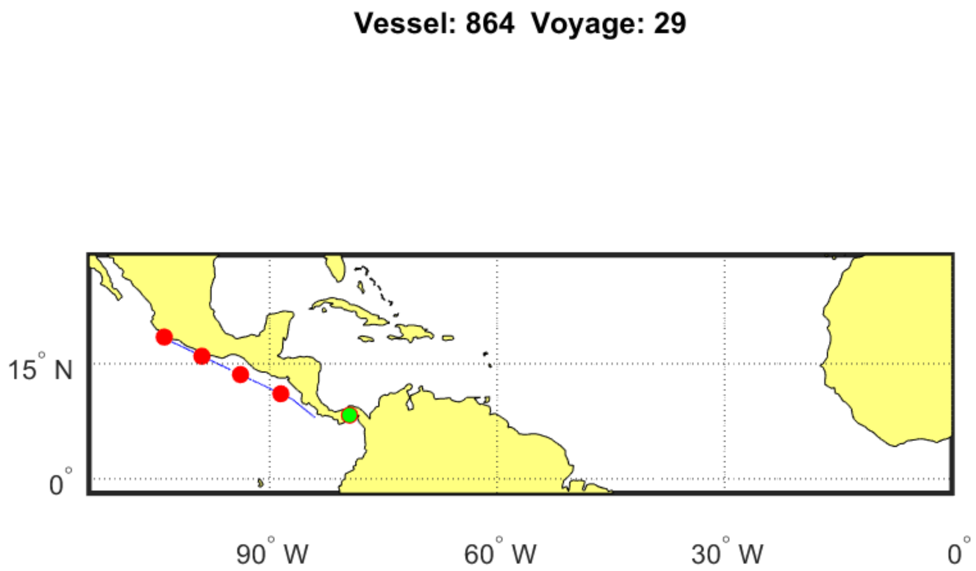
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
7	2	29	29	14.26	552.3	25.32	
9	24	326	322	13.43	715.7	30.93	
10	24	344	346	14.46	676.2	31.47	
11	24	326	331	13.83	708.3	31.48	
12	24	320	329	13.72	700.1	30.86	

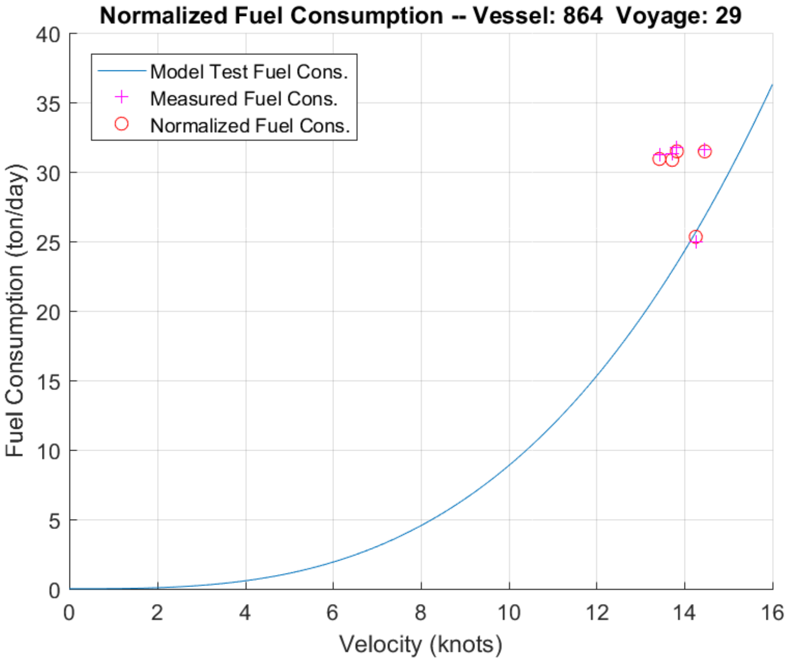
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to draft.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 5 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 30

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
7	24-Oct-2016 05:00:00	24-Oct-2016 19:00:00	9.20	0.00 40.43	0.00 42.20	14.60 42.43

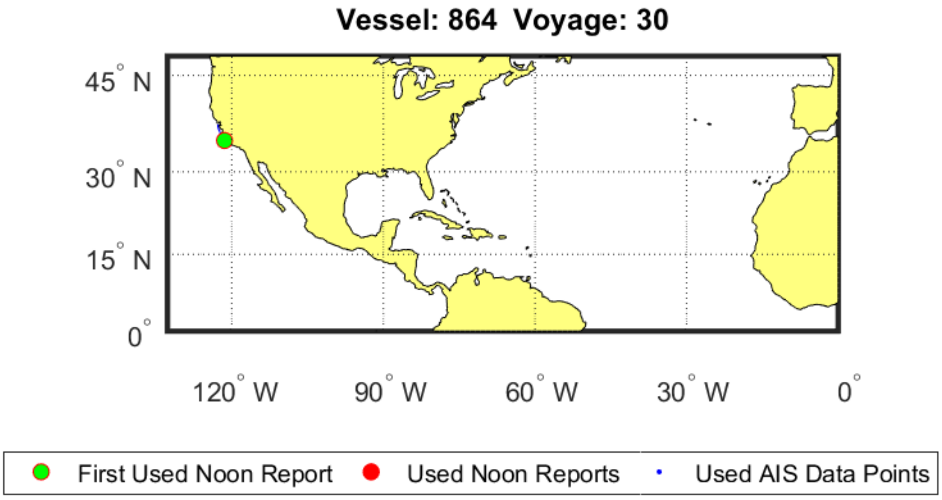
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
7	14	167	170	12.11	664.8	26.11	

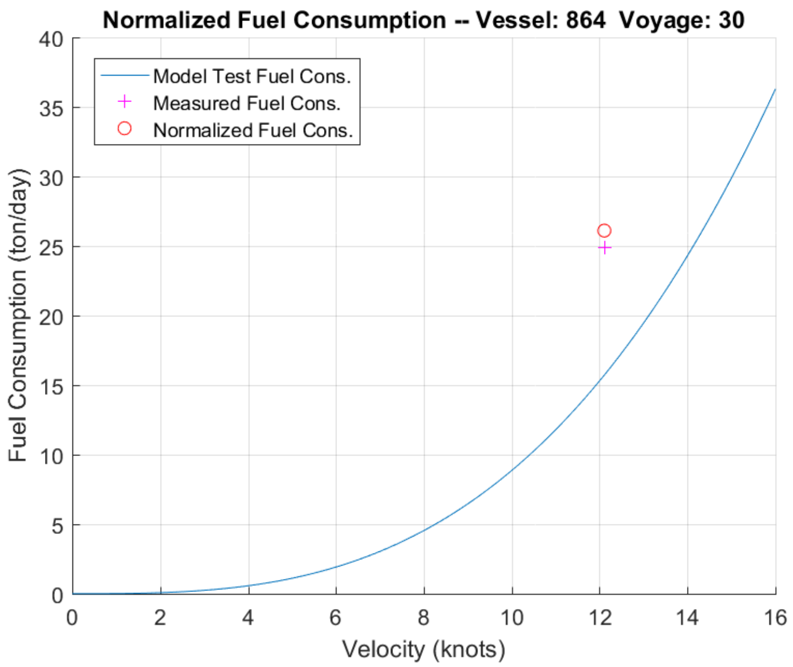
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 864; Voyage Name: 1601

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
6	25-Nov-2016 22:00:00	26-Nov-2016 20:00:00	10.52	0.00 40.43	0.00 42.20	23.80 42.43
10	30-Nov-2016 19:00:00	01-Dec-2016 19:00:00	11.80	25.00 40.43	0.00 42.20	0.00 42.43
13	03-Dec-2016 18:00:00	04-Dec-2016 18:00:00	11.80	28.50 40.43	0.00 42.20	0.00 42.43
15	05-Dec-2016 17:00:00	06-Dec-2016 17:00:00	11.80	29.70 40.43	0.00 42.20	0.00 42.43
16	06-Dec-2016 17:00:00	07-Dec-2016 17:00:00	11.80	29.30 40.43	0.00 42.20	0.00 42.43
18	08-Dec-2016 16:00:00	09-Dec-2016 16:00:00	11.80	28.50 40.43	0.00 42.20	0.00 42.43
19	09-Dec-2016 16:00:00	10-Dec-2016 16:00:00	11.80	29.00 40.43	0.00 42.20	0.00 42.43
21	11-Dec-2016 16:00:00	12-Dec-2016 15:00:00	11.80	26.90 40.43	0.00 42.20	0.00 42.43

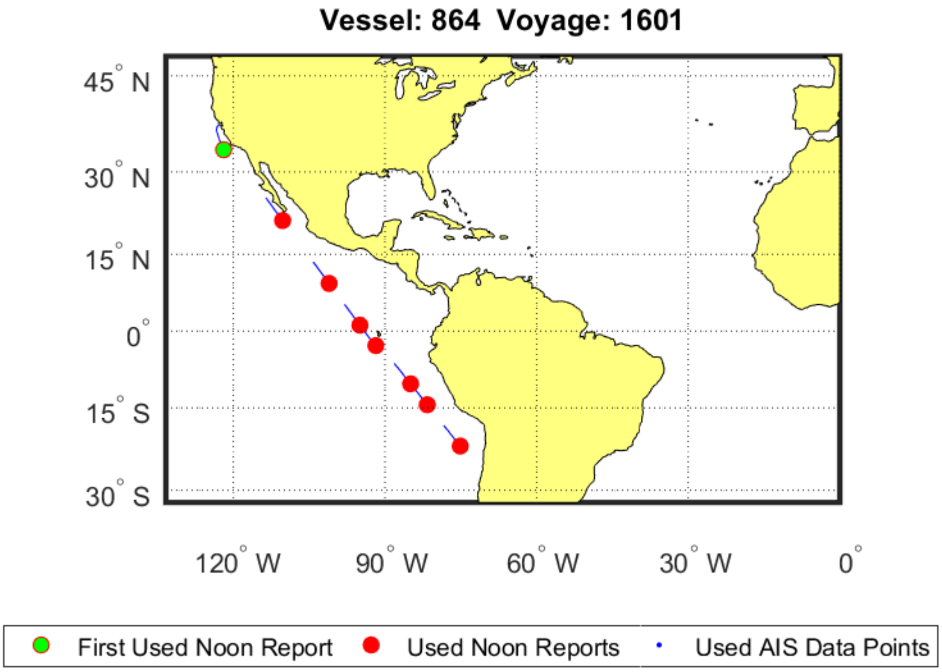
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
6	22	263	260	11.84	685.6	26.15	
10	24	307	307	12.81	568.1	23.39	
13	24	310	316	13.19	619.7	26.25	
15	24	302	306	12.76	657.6	26.96	
16	24	313	322	13.45	615.7	26.72	
18	24	305	308	12.86	624.5	25.79	
19	24	308	309	12.89	629.8	26.10	
21	23	292	297	12.91	602.9	24.99	

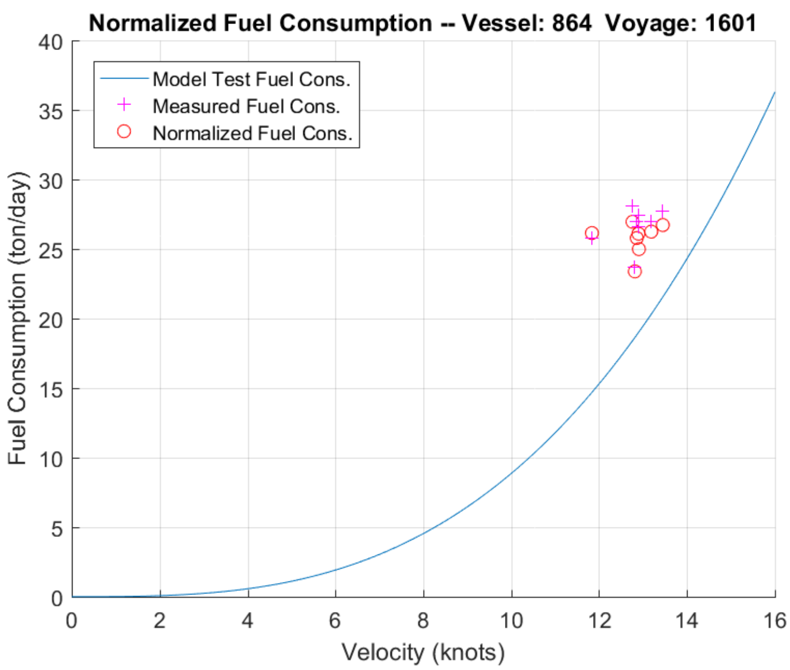
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.
Noon Report 12 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.
Noon Report 17 filtered out due to inconsistent AIS/NR lengths.
Noon Report 20 filtered out due to inconsistent AIS/NR lengths.
Noon Report 22 filtered out due to inconsistent AIS/NR lengths.
Noon Report 23 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 22

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
16	13-Nov-2015 17:00:00	14-Nov-2015 17:00:00	11.70	18.60 40.30	0.00 42.20	0.00 42.20
17	14-Nov-2015 17:00:00	15-Nov-2015 18:00:00	11.70	24.80 40.30	0.00 42.20	0.00 42.20
20	17-Nov-2015 18:00:00	18-Nov-2015 18:00:00	11.70	24.80 40.30	0.00 42.20	0.00 42.20
21	18-Nov-2015 18:00:00	19-Nov-2015 18:00:00	11.70	24.50 40.30	0.00 42.20	0.00 42.20
22	19-Nov-2015 19:00:00	20-Nov-2015 19:00:00	11.70	24.50 40.30	0.00 42.20	0.00 42.20
23	20-Nov-2015 19:00:00	21-Nov-2015 20:00:00	11.05	24.80 40.30	0.00 42.20	0.00 42.20
24	21-Nov-2015 20:00:00	22-Nov-2015 20:00:00	11.05	23.40 40.30	0.00 42.20	0.00 42.20

AIS Calculated Data:

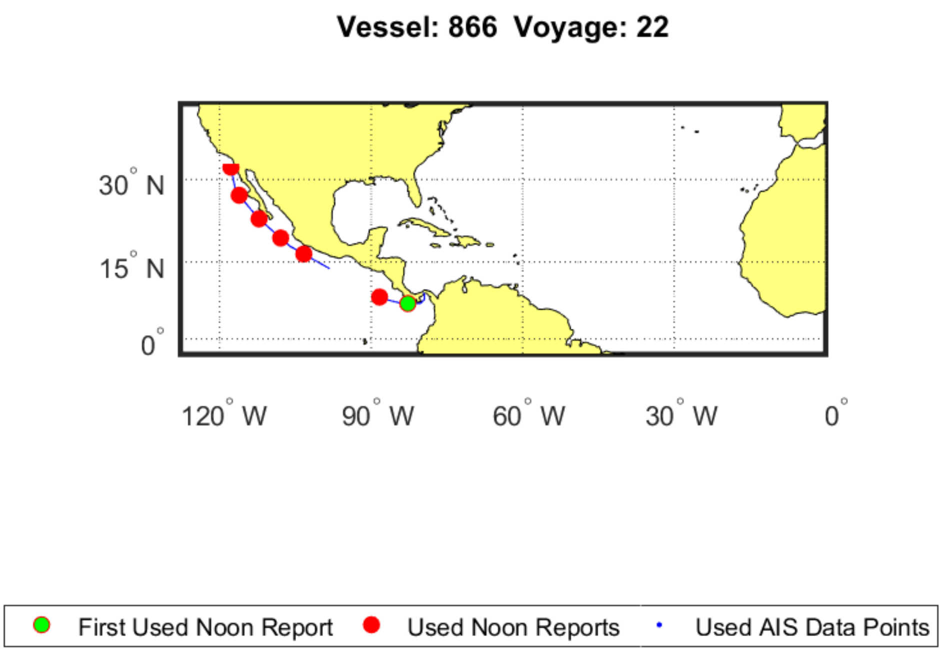
NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
16	24	301	NaN	NaN	NaN	NaN	**
17	25	343	340	13.65	499.5	21.92	
20	24	336	331	13.83	516.4	22.96	
21	24	307	304	12.79	517.8	21.34	
22	24	315	314	13.21	490.7	20.82	
23	25	329	330	13.21	486.6	20.66	
24	24	305	306	12.73	499.1	21.31	

Filtered Data:

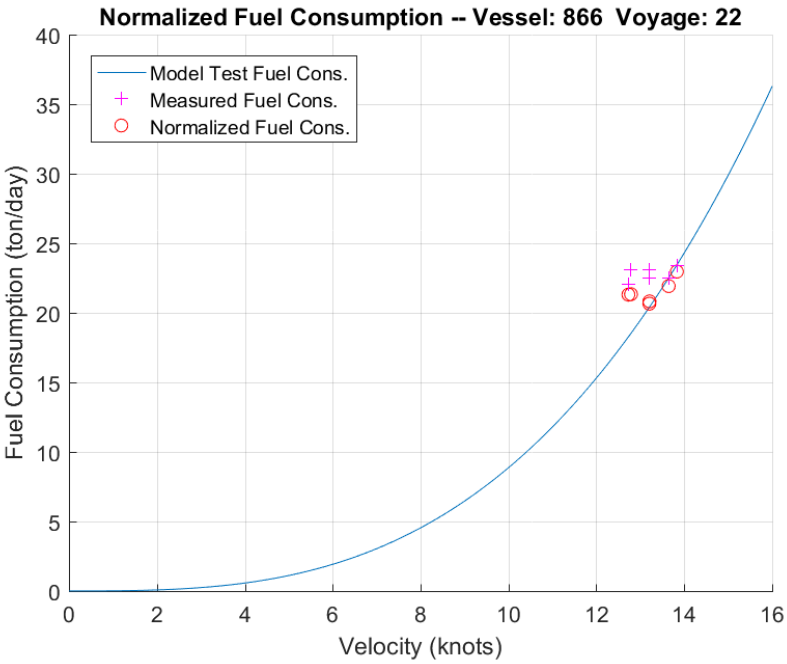
Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.

Noon Report 5 filtered out due to inconsistent AIS/NR lengths.
Noon Report 7 filtered out due to inconsistent AIS/NR lengths.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 10 filtered out due to inconsistent AIS/NR lengths.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.
Noon Report 12 filtered out due to inconsistent AIS/NR lengths.
Noon Report 13 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.
Noon Report 15 filtered out due to inconsistent AIS/NR lengths.
Noon Report 18 filtered out due to inconsistent AIS/NR lengths.
Noon Report 19 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to lack of AIS data.
Noon Report 6 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 23

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
9	12-Dec-2015 01:00:00	12-Dec-2015 08:00:00	10.90	0.00 40.30	0.00 42.20	6.20 42.20

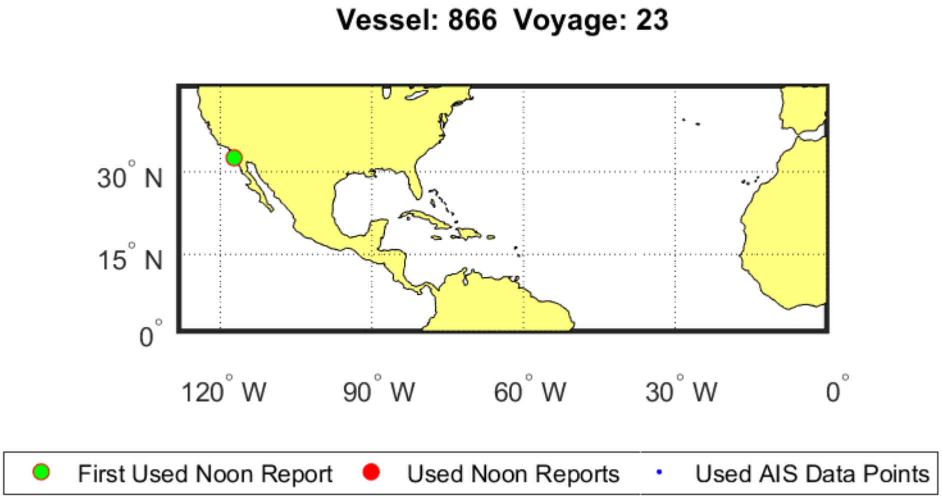
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
9	7	89	89	12.74	569.3	23.38	

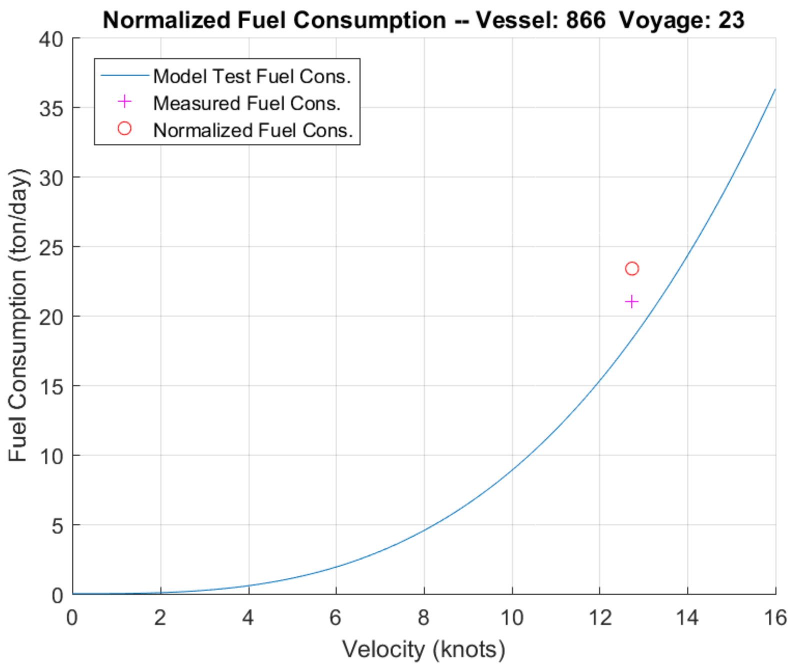
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 24

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
5	07-Jan-2016 20:00:00	08-Jan-2016 20:00:00	10.40	0.00 40.30	0.00 42.20	25.50 42.20
7	09-Jan-2016 19:00:00	10-Jan-2016 19:00:00	10.40	25.20 40.30	0.00 42.20	0.00 42.20
8	10-Jan-2016 19:00:00	11-Jan-2016 19:00:00	10.20	25.20 40.30	0.00 42.20	0.00 42.20
9	11-Jan-2016 19:00:00	12-Jan-2016 18:00:00	10.20	24.50 40.30	0.00 42.20	0.00 42.20

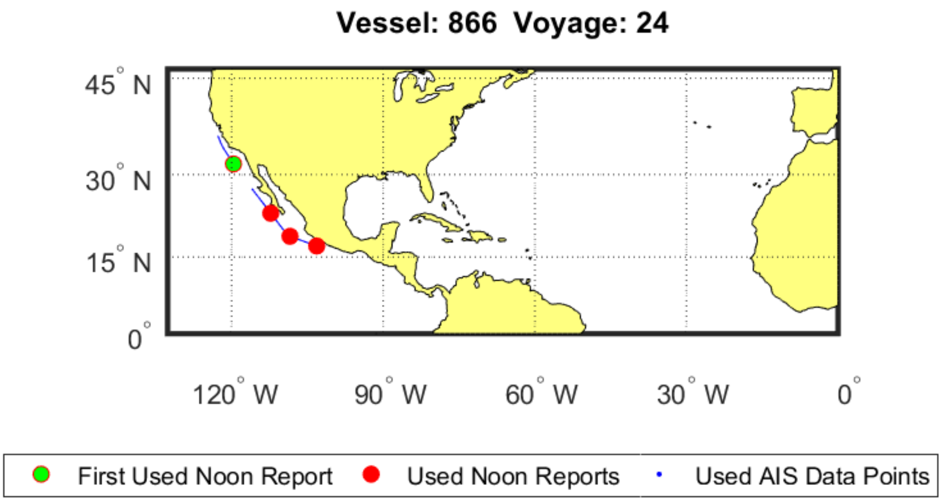
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
5	24	319	320	13.38	639.4	27.52	
7	24	335	338	14.10	580.1	26.28	
8	24	335	338	14.14	569.3	25.86	
9	23	320	319	13.88	583.9	26.03	

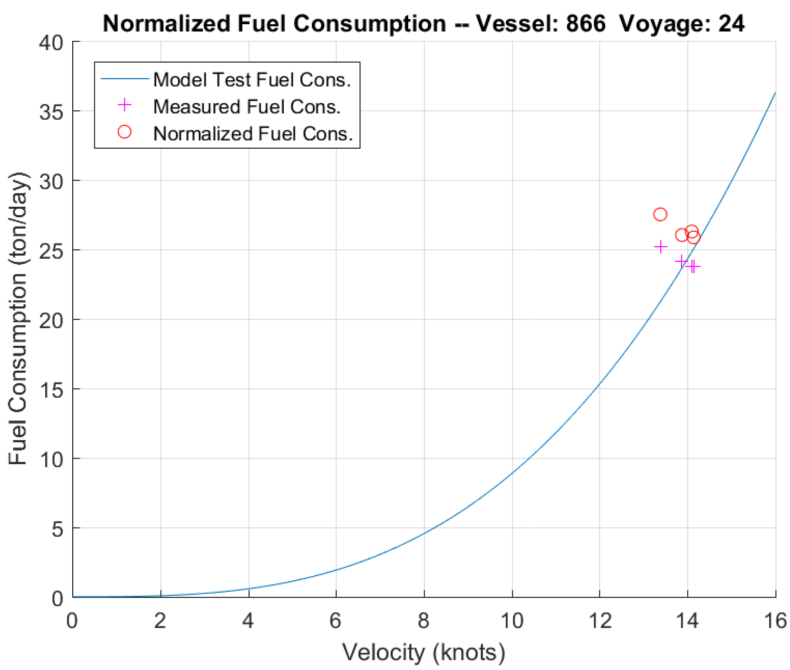
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 10 filtered out due to inconsistent AIS/NR lengths.
Noon Report 11 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 25

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
10	01-Feb-2016 18:00:00	02-Feb-2016 18:00:00	10.60	14.30 40.30	0.00 42.20	7.90 42.20
11	02-Feb-2016 18:00:00	03-Feb-2016 17:00:00	10.60	21.30 40.30	0.00 42.20	0.00 42.20
12	03-Feb-2016 17:00:00	04-Feb-2016 17:00:00	10.60	22.10 40.30	0.00 42.20	0.00 42.20
13	04-Feb-2016 17:00:00	05-Feb-2016 17:00:00	10.60	27.70 40.30	0.00 42.20	0.00 42.20
16	11-Feb-2016 17:00:00	12-Feb-2016 17:00:00	11.40	25.20 40.30	0.00 42.20	0.00 42.20
17	12-Feb-2016 17:00:00	13-Feb-2016 18:00:00	10.40	26.30 40.30	0.00 42.20	0.00 42.20

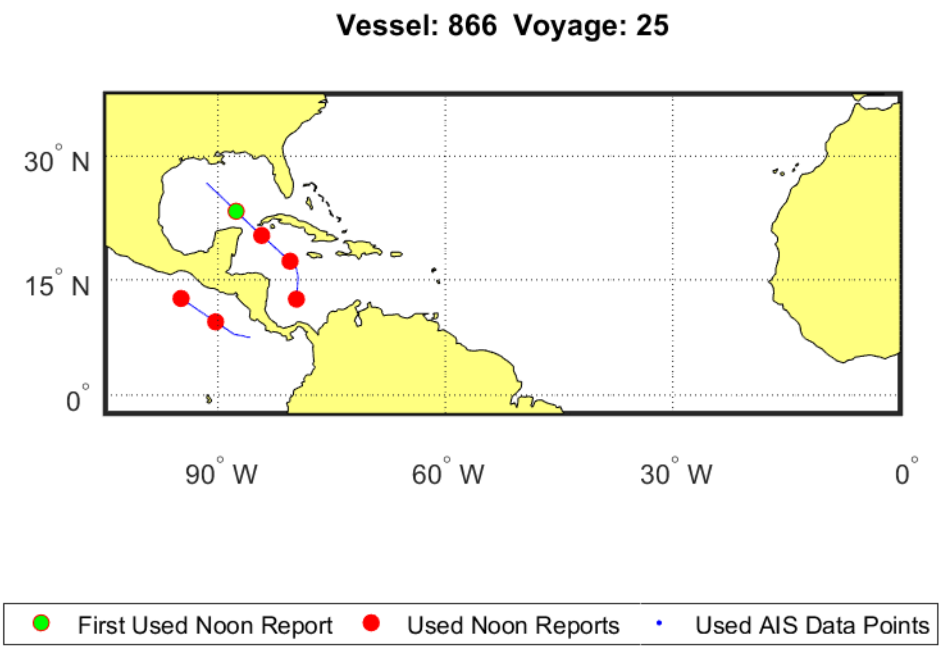
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
10	24	298	295	12.33	518.0	20.74	
11	23	257	276	12.02	481.1	18.69	
12	24	284	288	12.04	484.5	18.78	
13	24	310	314	13.12	638.8	27.06	
16	24	306	300	12.52	592.7	23.97	
17	25	320	303	12.16	602.4	23.89	

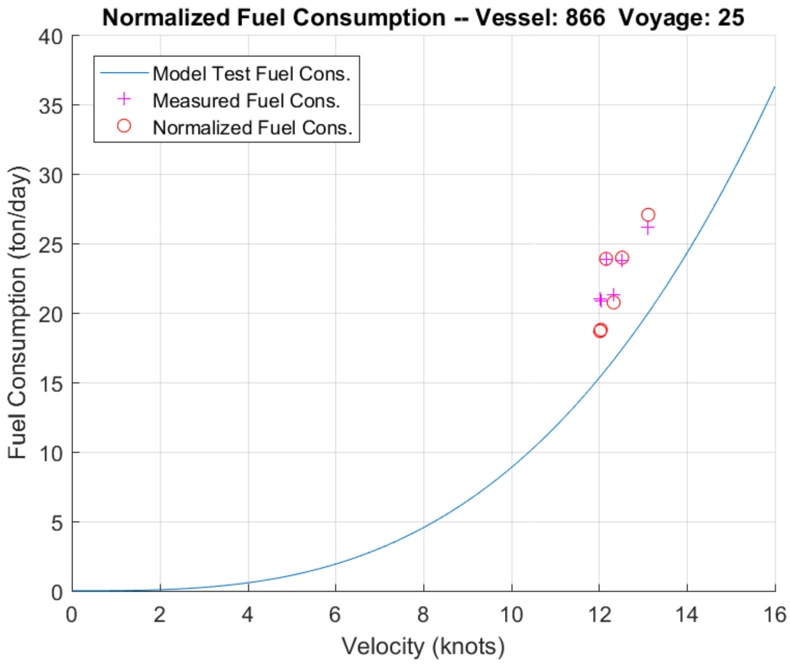
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 20 filtered out due to draft.
Noon Report 21 filtered out due to draft.
Noon Report 22 filtered out due to draft.
Noon Report 23 filtered out due to draft.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.
Noon Report 15 filtered out due to inconsistent AIS/NR lengths.
Noon Report 18 filtered out due to inconsistent AIS/NR lengths.
Noon Report 19 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 26

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
16	10-Mar-2016 20:00:00	11-Mar-2016 20:00:00	10.60	0.00 40.30	0.00 42.20	25.40 42.20
17	11-Mar-2016 20:00:00	12-Mar-2016 20:00:00	10.60	0.00 40.30	0.00 42.20	28.90 42.20
18	12-Mar-2016 20:00:00	13-Mar-2016 20:00:00	10.60	0.00 40.30	0.00 42.20	29.70 42.20
19	13-Mar-2016 20:00:00	14-Mar-2016 20:00:00	10.60	1.30 40.30	0.00 42.20	27.00 42.20

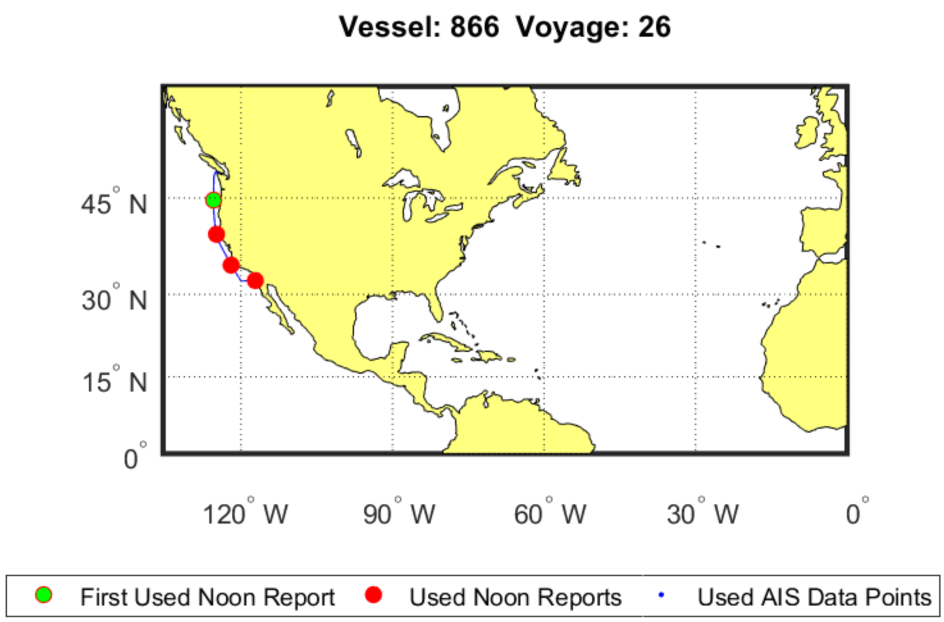
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
16	24	266	270	11.24	635.2	23.54	**
17	24	301	299	12.47	709.2	29.23	
18	24	322	319	13.28	692.7	29.62	
19	24	326	324	13.50	664.9	29.46	**

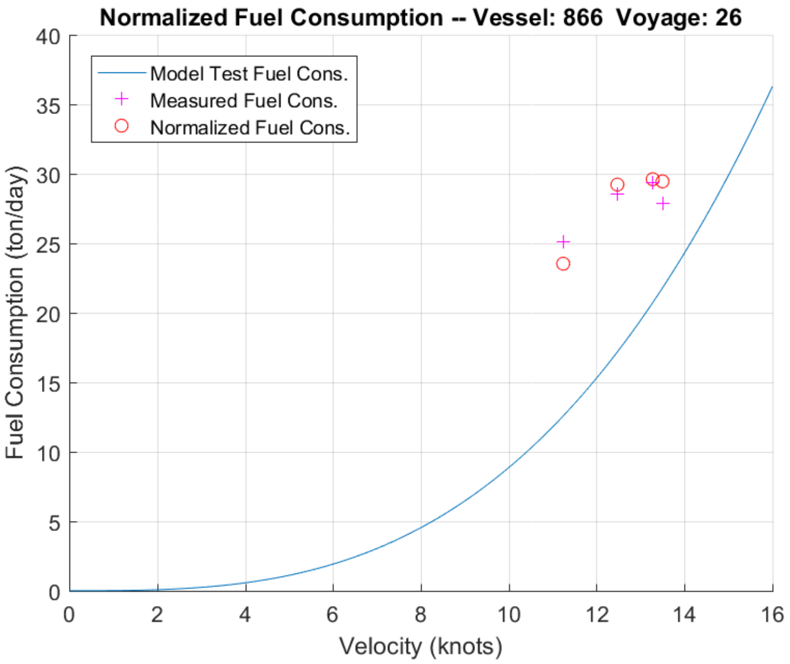
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 10 filtered out due to draft.
Noon Report 11 filtered out due to draft.
Noon Report 12 filtered out due to draft.
Noon Report 13 filtered out due to draft.
Noon Report 14 filtered out due to draft.
Noon Report 15 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 27

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
10	02-Apr-2016 16:00:00	02-Apr-2016 19:00:00	10.82	0.00 40.20	0.00 42.20	3.40 42.30
11	02-Apr-2016 19:00:00	03-Apr-2016 19:00:00	10.82	0.00 40.20	0.00 42.20	28.30 42.30
12	03-Apr-2016 19:00:00	04-Apr-2016 19:00:00	10.82	28.42 40.20	0.00 42.20	1.60 42.30
13	04-Apr-2016 19:00:00	05-Apr-2016 20:00:00	10.60	32.20 40.20	0.00 42.20	0.00 42.30
14	05-Apr-2016 20:00:00	06-Apr-2016 21:00:00	10.60	32.70 40.20	0.00 42.20	0.00 42.30
15	06-Apr-2016 21:00:00	07-Apr-2016 22:00:00	10.60	31.10 40.20	0.00 42.20	0.00 42.30
16	08-Apr-2016 23:00:00	09-Apr-2016 23:00:00	10.60	31.80 40.20	0.00 42.20	0.00 42.30
17	09-Apr-2016 23:00:00	11-Apr-2016	10.60	31.20 40.20	0.00 42.20	0.00 42.30
18	11-Apr-2016	12-Apr-2016	10.60	29.10 40.20	0.00 42.20	0.00 42.30
19	12-Apr-2016	13-Apr-2016 01:00:00	10.60	30.30 40.20	0.00 42.20	0.00 42.30
20	13-Apr-2016 01:00:00	14-Apr-2016 01:00:00	10.60	30.50 40.20	0.00 42.20	0.00 42.30
21	14-Apr-2016 01:00:00	15-Apr-2016 02:00:00	10.60	32.00 40.20	0.00 42.20	0.00 42.30
22	15-Apr-2016 02:00:00	16-Apr-2016 02:00:00	10.60	28.20 40.20	0.00 42.20	0.00 42.30

23	16-Apr-2016 02:00:00	17-Apr-2016 02:00:00	10.60	30.20 40.20	0.00 42.20	0.00 42.30
24	17-Apr-2016 02:00:00	18-Apr-2016 03:00:00	10.60	32.60 40.20	0.00 42.20	0.00 42.30
25	18-Apr-2016 03:00:00	19-Apr-2016 03:00:00	10.60	28.40 40.20	0.00 42.20	0.00 42.30
26	19-Apr-2016 03:00:00	20-Apr-2016 03:00:00	10.60	28.50 40.20	0.00 42.20	0.00 42.30
27	20-Apr-2016 03:00:00	21-Apr-2016 04:00:00	10.60	30.10 40.20	0.00 42.20	0.00 42.30
28	21-Apr-2016 04:00:00	22-Apr-2016 04:00:00	10.60	28.70 40.20	0.00 42.20	0.00 42.30
29	22-Apr-2016 04:00:00	23-Apr-2016 04:00:00	10.60	28.60 40.20	0.00 42.20	0.00 42.30
31	25-Apr-2016 04:00:00	25-Apr-2016 22:00:00	10.60	13.20 40.20	0.00 42.20	0.00 42.30

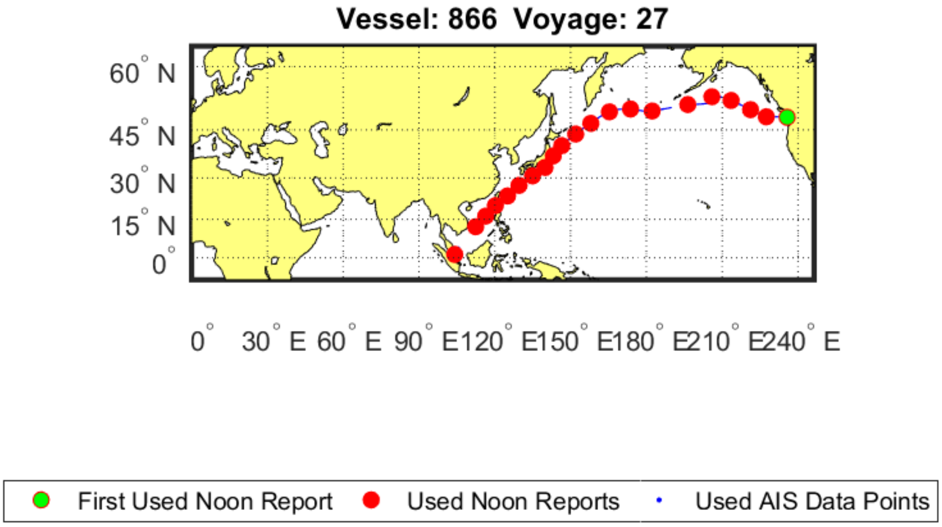
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resistance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
10	3	40	NaN	NaN	NaN	NaN	**
11	24	328	328	13.71	615.1	27.11	**
12	24	268	271	11.34	578.8	22.18	
13	25	317	319	12.78	709.2	29.17	
14	25	301	303	12.12	708.3	27.65	
15	25	331	332	13.30	541.4	23.15	
16	24	299	301	12.58	607.8	24.63	
17	25	333	331	13.28	626.5	26.73	
18	24	324	322	13.46	551.1	23.84	
19	25	346	343	13.77	610.3	27.00	
20	24	308	310	12.92	561.9	23.41	
21	25	318	322	12.87	456.5	18.96	
22	24	252	234	9.76	808.9	27.52	
23	24	287	301	12.53	696.4	28.30	
24	25	302	316	12.62	652.5	26.78	
25	24	343	336	13.99	610.7	27.48	
26	24	335	329	13.73	664.2	29.34	
27	25	344	343	13.71	645.2	28.47	
28	24	322	322	13.41	653.6	28.25	
29	24	334	333	13.87	635.1	28.33	
31	18	220	222	12.36	439.8	17.66	**

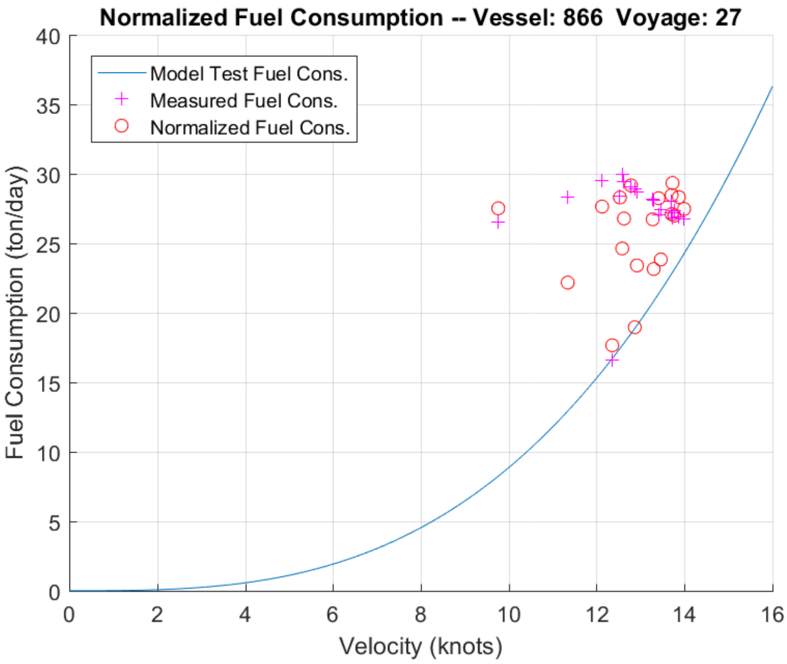
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to draft.
Noon Report 7 filtered out due to draft.
Noon Report 8 filtered out due to draft.
Noon Report 9 filtered out due to draft.
Noon Report 30 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 29

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
1	17-May-2016 23:00:00	18-May-2016 06:00:00	9.10	10.20 40.20	0.00 42.20	0.00 42.30
7	23-May-2016 07:00:00	24-May-2016 08:00:00	9.10	34.50 40.20	0.00 42.20	0.00 42.30
8	24-May-2016 08:00:00	25-May-2016 08:00:00	9.10	33.10 40.20	0.00 42.20	0.00 42.30
9	25-May-2016 08:00:00	26-May-2016 08:00:00	9.10	32.80 40.20	0.00 42.20	0.00 42.30
10	26-May-2016 08:00:00	27-May-2016 04:00:00	9.10	23.70 40.20	0.00 42.20	0.00 42.30

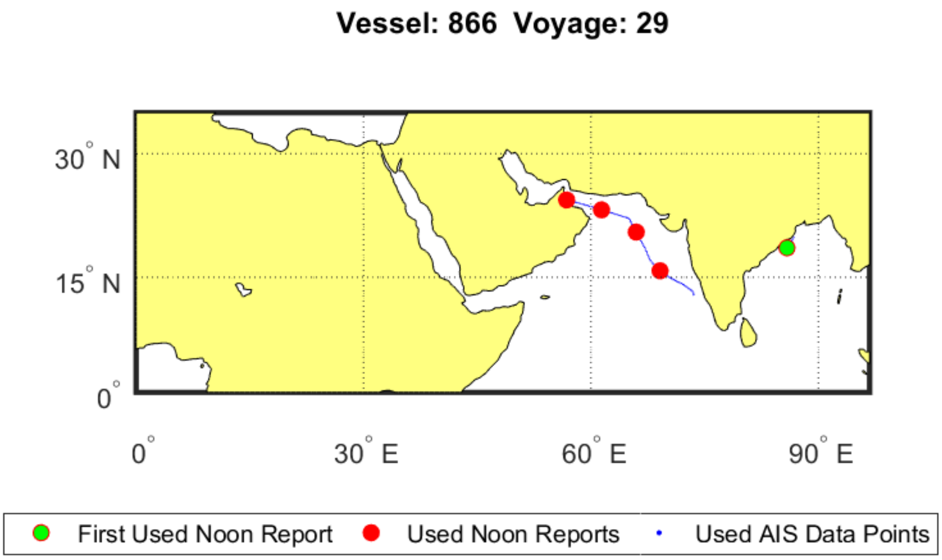
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
1	7	96	100	14.33	701.1	32.32	
7	25	335	345	13.81	769.6	34.17	
8	24	345	342	14.27	759.1	34.80	
9	24	325	331	13.83	763.3	33.93	
10	20	261	265	13.28	686.8	29.56	

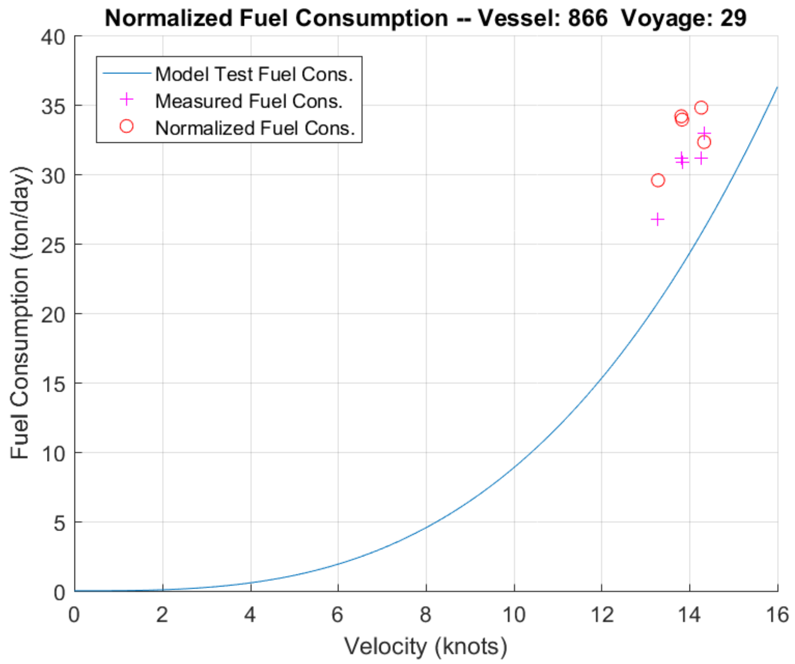
Filtered Data:

Noon Report 2 filtered out due to inconsistent AIS/NR lengths.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 5 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 30

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
6	10-Jun-2016 01:00:00	10-Jun-2016 08:00:00	10.00	10.00 40.20	0.00 42.20	0.00 42.30
7	10-Jun-2016 08:00:00	11-Jun-2016 08:00:00	10.00	29.50 40.20	0.00 42.20	0.00 42.30
15	18-Jun-2016 09:00:00	19-Jun-2016 09:00:00	10.00	29.00 40.20	0.00 42.20	0.00 42.30
16	19-Jun-2016 09:00:00	20-Jun-2016 10:00:00	10.00	31.50 40.20	0.00 42.20	0.00 42.30
17	20-Jun-2016 10:00:00	21-Jun-2016 10:00:00	10.00	31.00 40.20	0.00 42.20	2.50 42.30
18	21-Jun-2016 10:00:00	21-Jun-2016 12:00:00	10.00	1.50 40.20	0.00 42.20	0.00 42.30

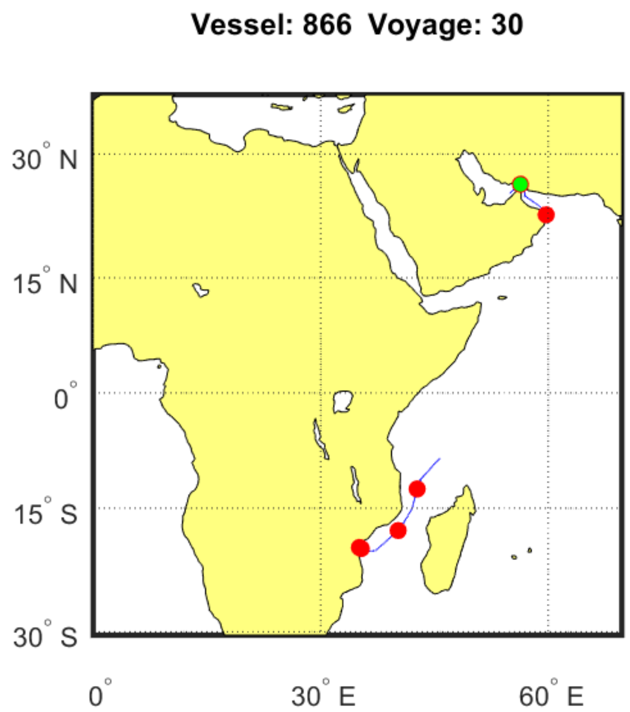
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis- tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
6	7	106	106	15.08	725.3	35.25	
7	24	313	312	12.99	694.2	30.08	
15	24	326	315	13.16	657.1	29.46	
16	25	351	341	13.66	662.6	29.13	
17	24	336	338	14.13	742.5	33.84	
18	2	17	17	8.42	615.8	18.37	

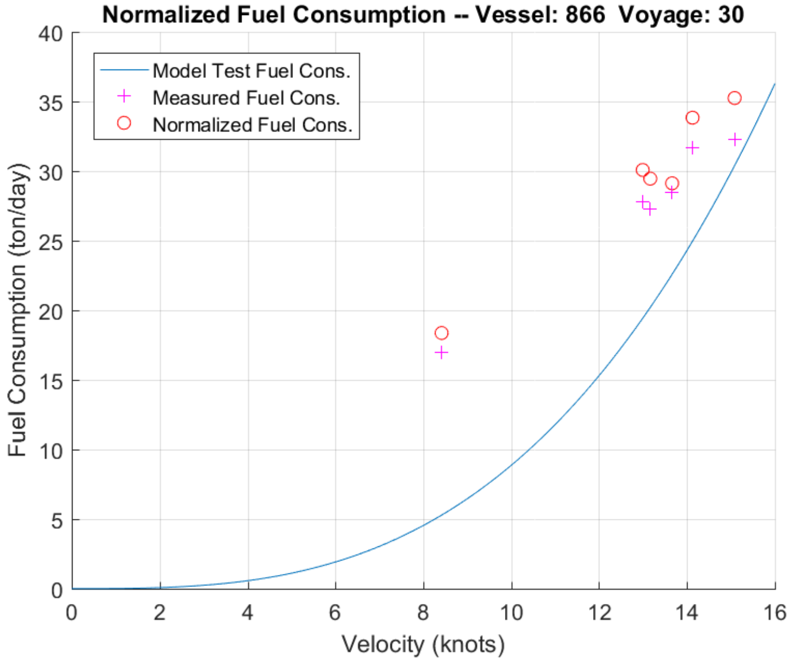
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 8 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to lack of AIS data.
Noon Report 10 filtered out due to lack of AIS data.
Noon Report 11 filtered out due to lack of AIS data.
Noon Report 12 filtered out due to lack of AIS data.
Noon Report 13 filtered out due to lack of AIS data.
Noon Report 14 filtered out due to lack of AIS data.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 34

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
5	02-Oct-2016 08:00:00	03-Oct-2016 04:00:00	10.65	10.10 40.20	0.00 42.20	0.00 42.30
7	04-Oct-2016 08:00:00	05-Oct-2016 08:00:00	10.65	24.80 40.20	0.00 42.20	0.00 42.30
8	05-Oct-2016 08:00:00	06-Oct-2016 08:00:00	10.65	26.20 40.20	0.00 42.20	0.00 42.30
9	06-Oct-2016 08:00:00	07-Oct-2016 08:00:00	10.65	27.50 40.20	0.00 42.20	0.00 42.30
10	07-Oct-2016 08:00:00	08-Oct-2016 08:00:00	10.65	26.60 40.20	0.00 42.20	0.00 42.30
11	08-Oct-2016 08:00:00	09-Oct-2016 08:00:00	10.65	26.90 40.20	0.00 42.20	0.00 42.30
12	09-Oct-2016 08:00:00	10-Oct-2016 08:00:00	10.65	25.90 40.20	0.00 42.20	0.00 42.30
13	10-Oct-2016 09:00:00	10-Oct-2016 17:00:00	10.65	11.20 40.20	0.00 42.20	0.00 42.30
15	15-Oct-2016 09:00:00	16-Oct-2016 09:00:00	9.00	27.40 40.20	0.00 42.20	0.00 42.30

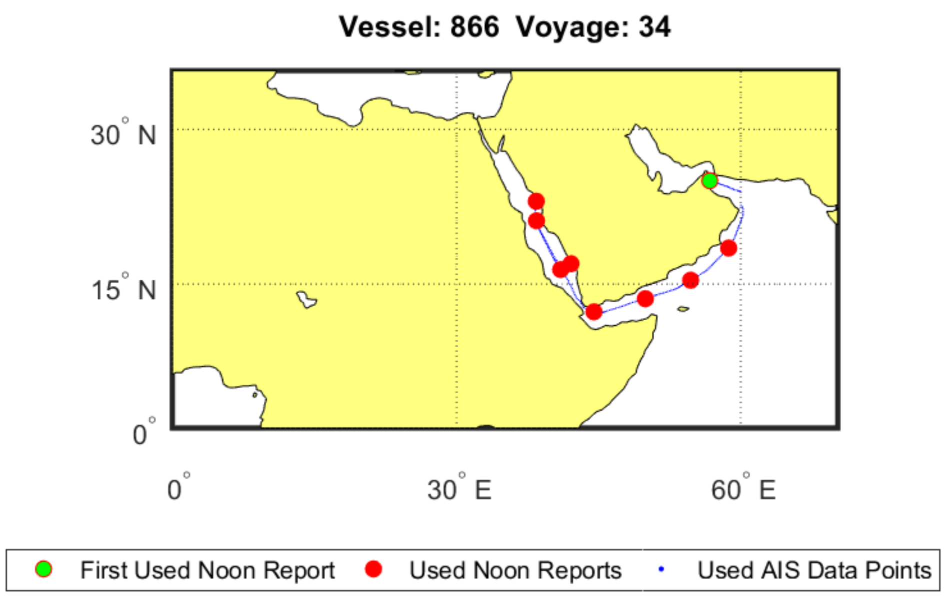
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
5	20	205	206	10.32	361.9	12.37	
7	24	285	294	12.29	528.7	21.28	
8	24	302	313	13.07	559.9	23.56	
9	24	301	325	13.54	599.9	26.24	
10	24	334	334	13.97	591.9	26.57	
11	24	332	331	13.82	603.1	26.81	**
12	24	326	325	13.59	582.5	25.75	**
13	8	108	107	13.42	755.2	32.62	**
15	24	339	339	14.14	647.1	29.40	**

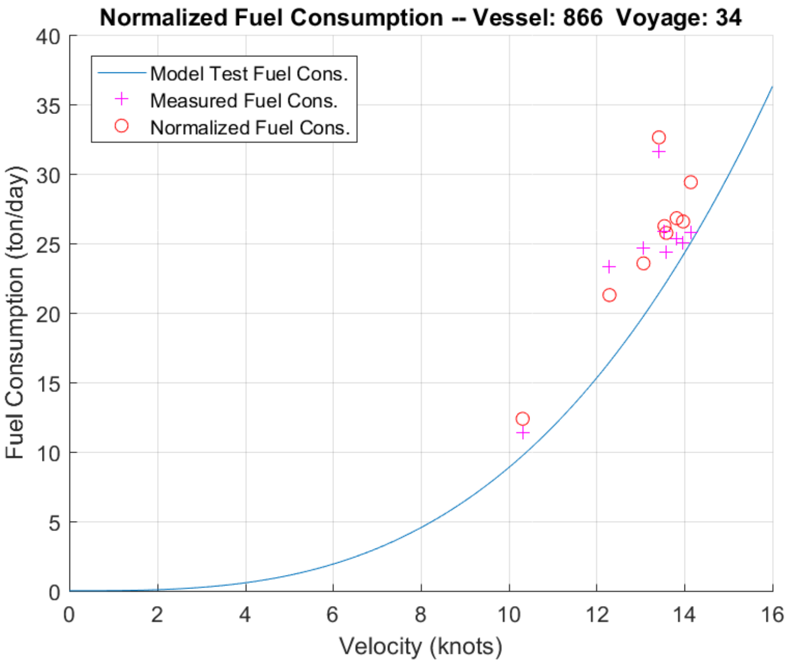
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to inconsistent AIS/NR lengths.
Noon Report 4 filtered out due to inconsistent AIS/NR lengths.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 35

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
4	27-Oct-2016 13:00:00	28-Oct-2016 10:00:00	10.65	18.10 40.20	0.00 42.20	0.00 42.30

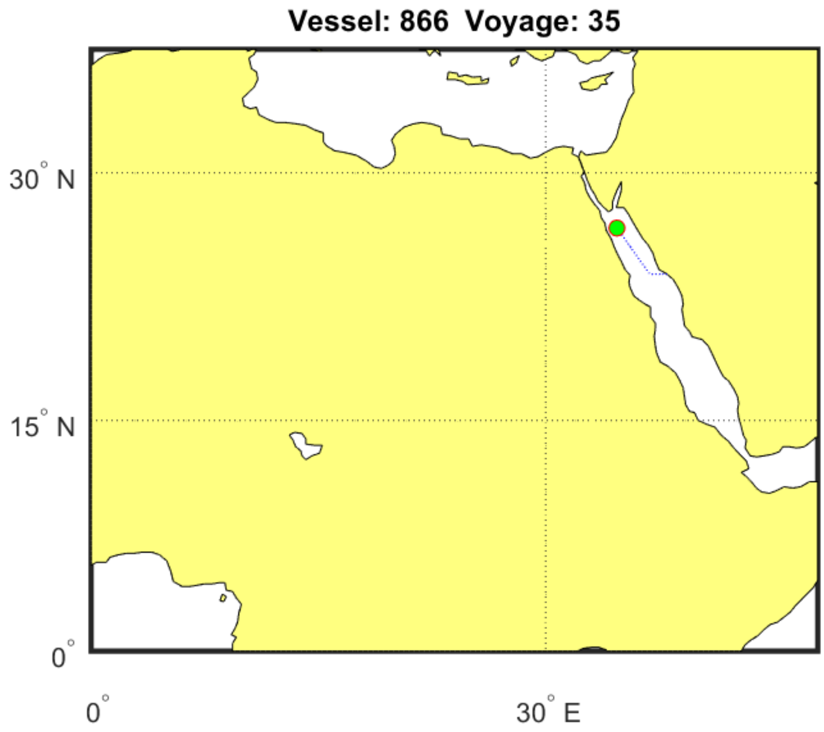
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
4	21	267	263	12.78	506.2	20.83	**

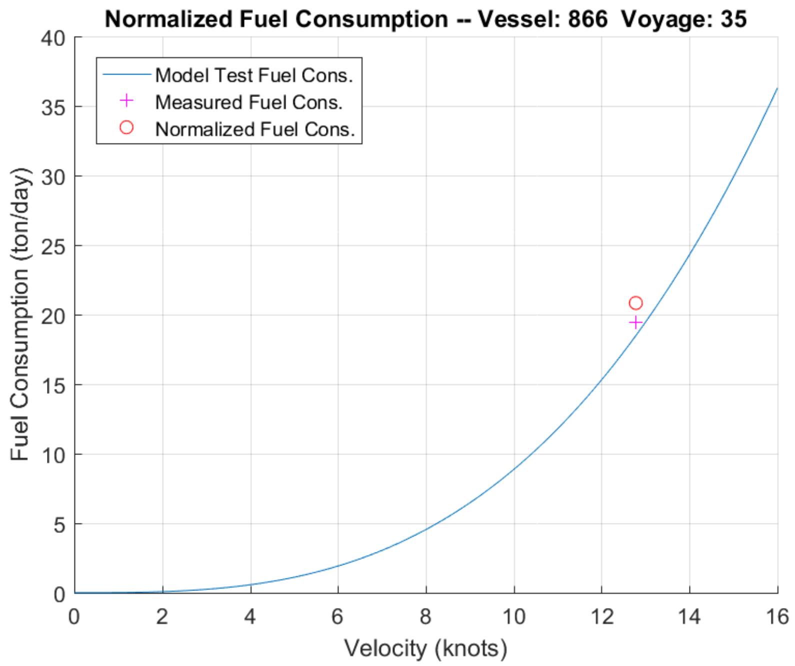
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 5 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



Vessel: 866; Voyage Name: 36

Vessel Type: MR

Filters:

Draft Range: ±2 meters
Speed Standard Deviation Maximum: 10 m/s
Heading Standard Deviation Maximum: 10 rad

Noon Report Data:

NR#	NR Start	NR End	Draft (m)	HFO (ton) LCV (MJ/kg)	MDO (ton) LCV (MJ/kg)	MGO (ton) LCV (MJ/kg)
7	17-Nov-2016 09:00:00	18-Nov-2016 09:00:00	10.70	27.40 40.20	0.00 42.20	0.00 42.30
8	18-Nov-2016 09:00:00	19-Nov-2016 04:00:00	10.70	24.20 40.20	0.00 42.20	0.00 42.30
10	19-Nov-2016 09:00:00	20-Nov-2016 09:00:00	10.70	27.60 40.20	0.00 42.20	0.00 42.30
11	20-Nov-2016 09:00:00	21-Nov-2016 09:00:00	10.70	27.10 40.20	0.00 42.20	0.00 42.30
12	21-Nov-2016 09:00:00	22-Nov-2016 09:00:00	10.70	26.80 40.20	0.00 42.20	0.00 42.30
13	22-Nov-2016 09:00:00	23-Nov-2016 09:00:00	10.70	26.90 40.20	0.00 42.20	0.00 42.30
15	24-Nov-2016 09:00:00	25-Nov-2016 09:00:00	10.70	28.50 40.20	0.00 42.20	0.00 42.30
16	25-Nov-2016 09:00:00	26-Nov-2016 09:00:00	10.70	28.20 40.20	0.00 42.20	0.00 42.30
17	26-Nov-2016 09:00:00	26-Nov-2016 16:00:00	10.70	8.30 40.20	0.00 42.20	0.00 42.30

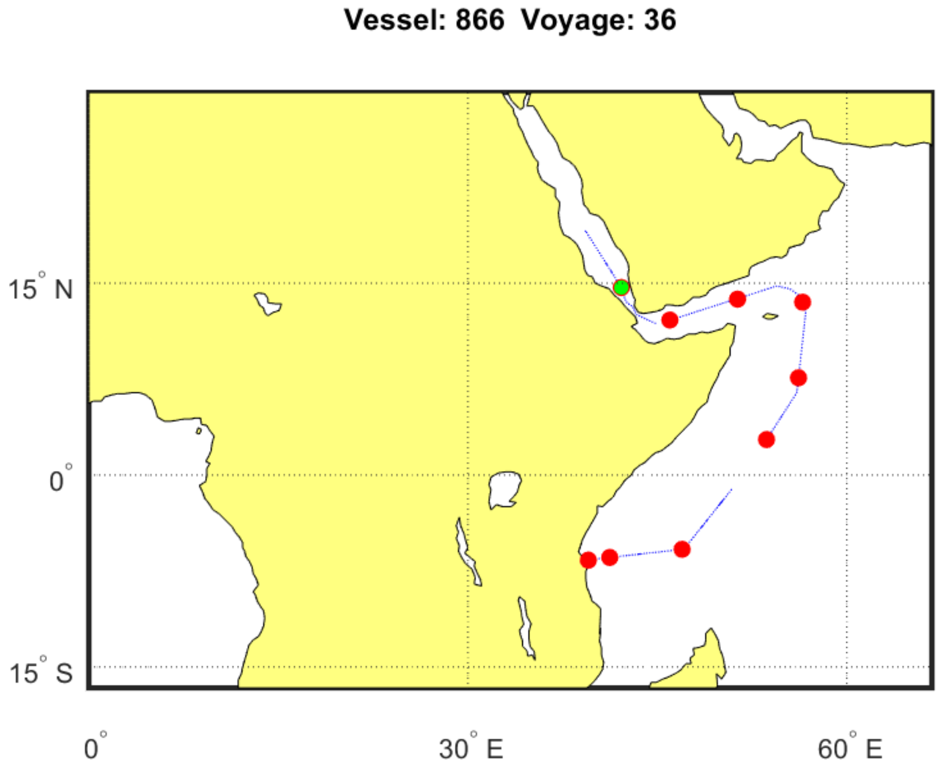
AIS Calculated Data:

NR#	Length (hr)	Observed Distance (NM)	Logged Distance (NM)	Speed Through Water (knots)	Norm. Resis-tance (kN)	Norm. Fuel Cons. (ton/day)	Missing Wave Info
7	24	308	313	13.14	602.3	26.18	**
8	19	244	258	13.60	651.5	28.54	**
10	24	332	344	14.35	569.9	26.29	
11	24	337	328	13.68	599.5	26.39	
12	24	354	351	14.68	560.2	26.45	
13	24	331	336	14.04	588.8	26.77	
15	24	326	324	13.61	638.7	27.96	
16	24	343	338	14.10	620.3	28.12	
17	7	101	102	14.54	607.9	28.38	

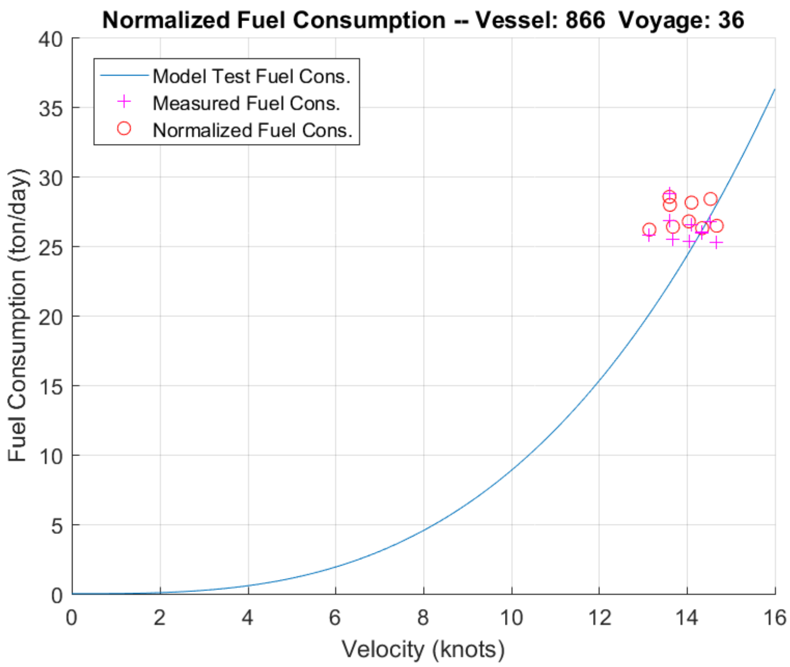
Filtered Data:

Noon Report 1 filtered out due to draft.
Noon Report 2 filtered out due to draft.
Noon Report 3 filtered out due to draft.
Noon Report 4 filtered out due to draft.
Noon Report 5 filtered out due to draft.
Noon Report 6 filtered out due to inconsistent AIS/NR lengths.
Noon Report 9 filtered out due to inconsistent AIS/NR lengths.
Noon Report 14 filtered out due to inconsistent AIS/NR lengths.

Voyage Map:



Fuel Consumption Plot:



3 Model 2 Output

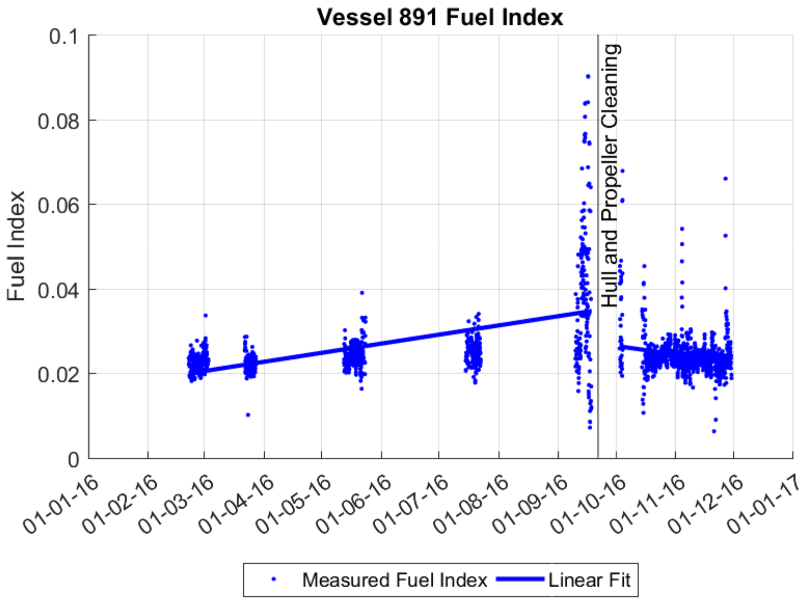
This section includes the output of Model 2.

Vessel: 891

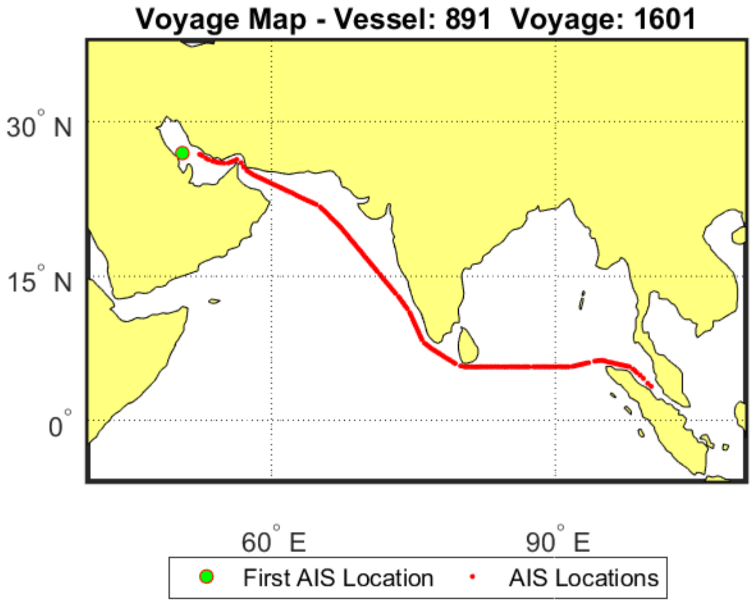
Filters:

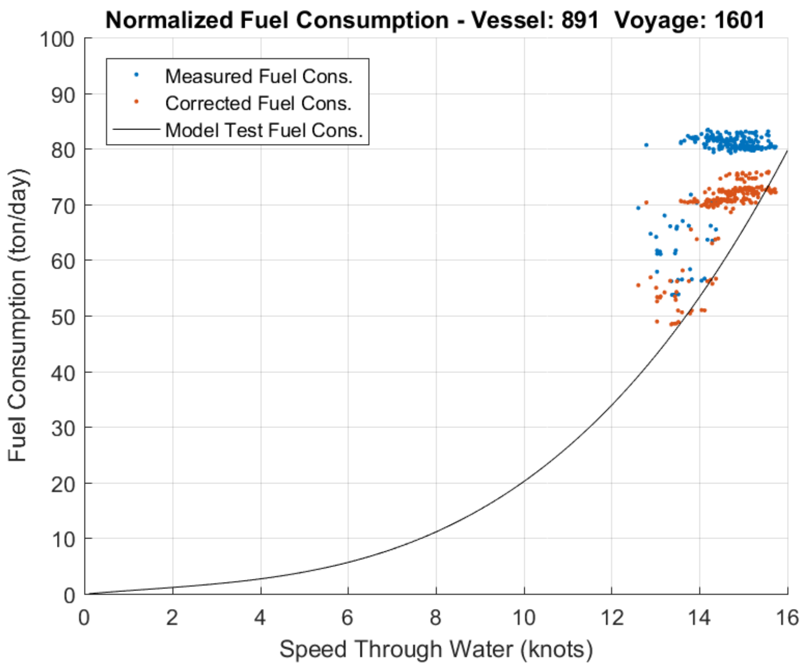
Draft Range: ±2 meters
Speed Standard Deviation Maximum: 0.1 m/s
Heading Standard Deviation Maximum: 0.1 rad

Fuel Index:

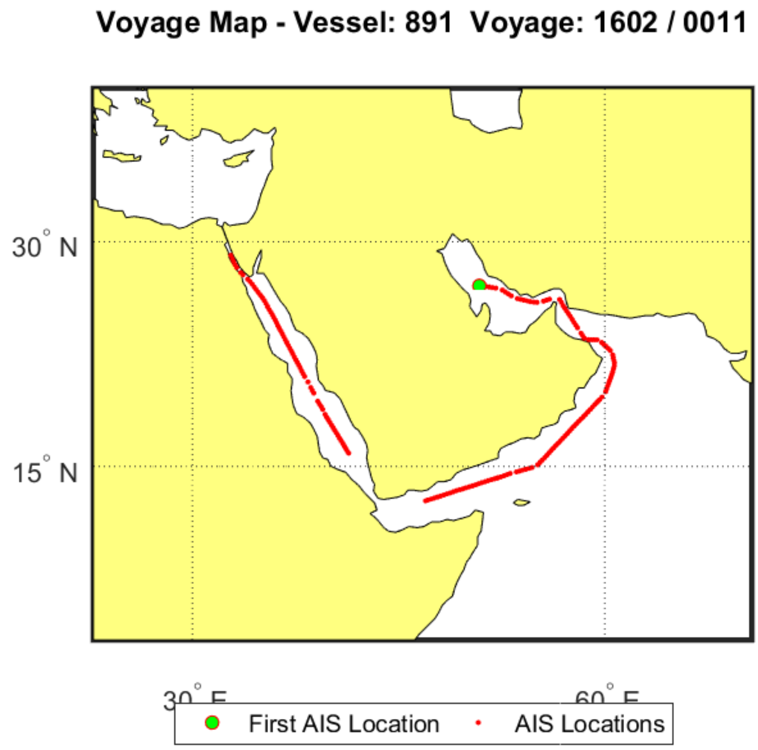


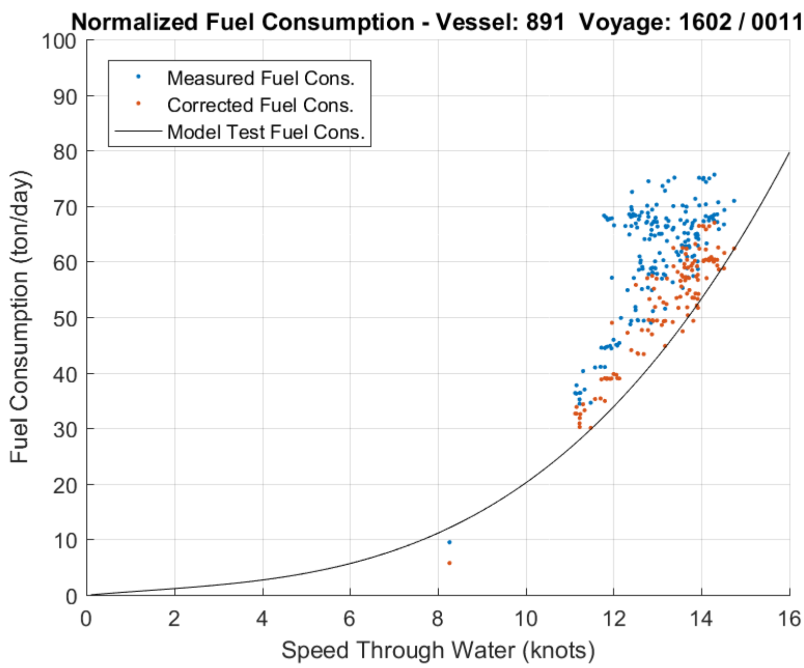
Voyage: 1601


Voyage Map - Vessel: 891 Voyage: 1601
30° N
15° N
0°
60° E
90° E
First AIS Location
AIS Locations

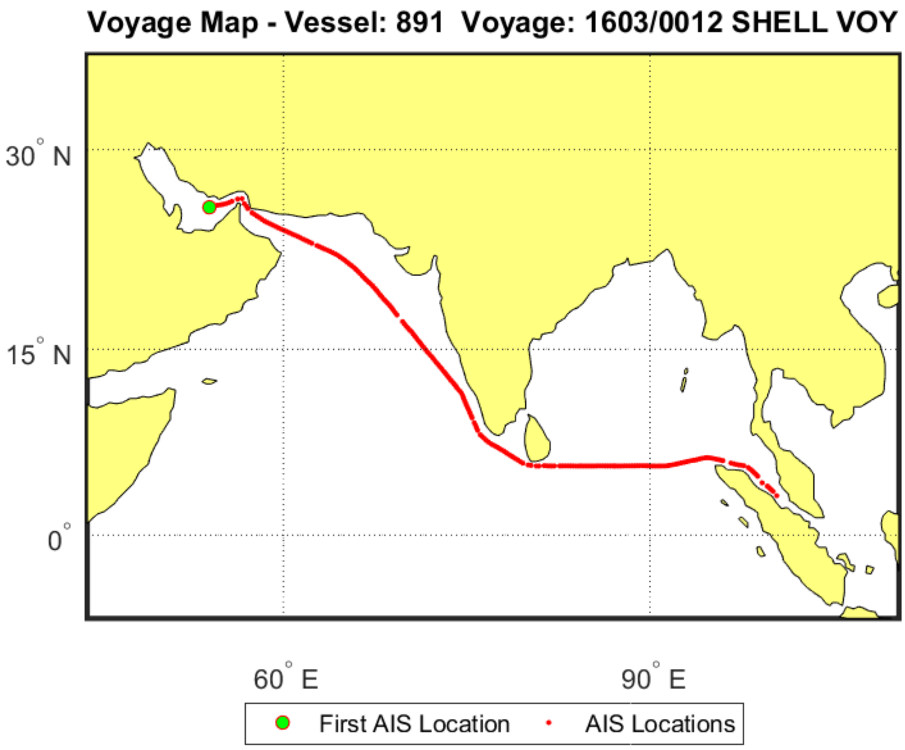

Normalized Fuel Consumption - Vessel: 891 Voyage: 1601
Measured Fuel Cons.
Corrected Fuel Cons.
Model Test Fuel Cons.
Fuel Consumption (ton/day)
Speed Through Water (knots)
0
10
20
30
40
50
60
70
80
90
100
0
2
4
6
8
10
12
14
16

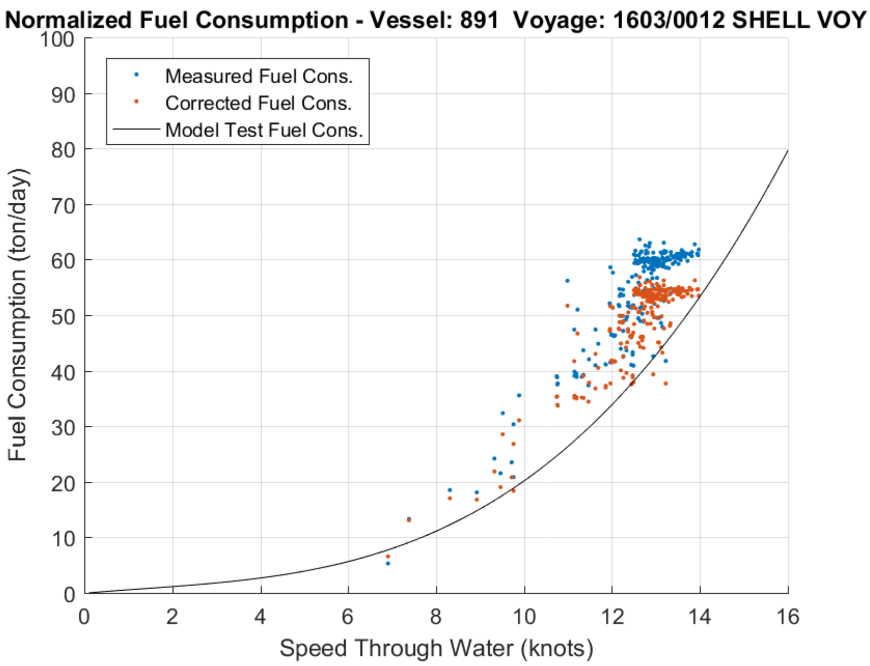
Voyage: 1602 / 0011



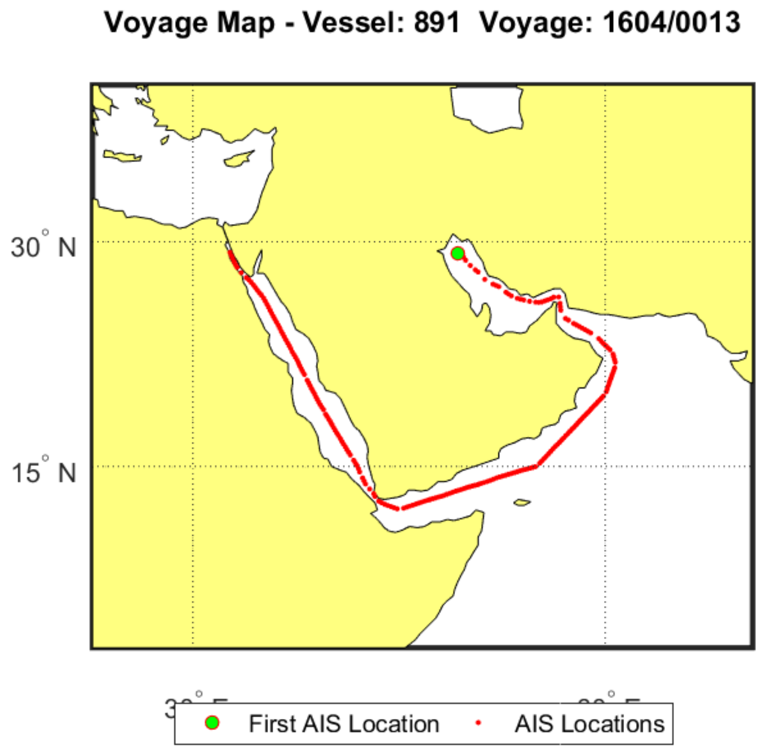


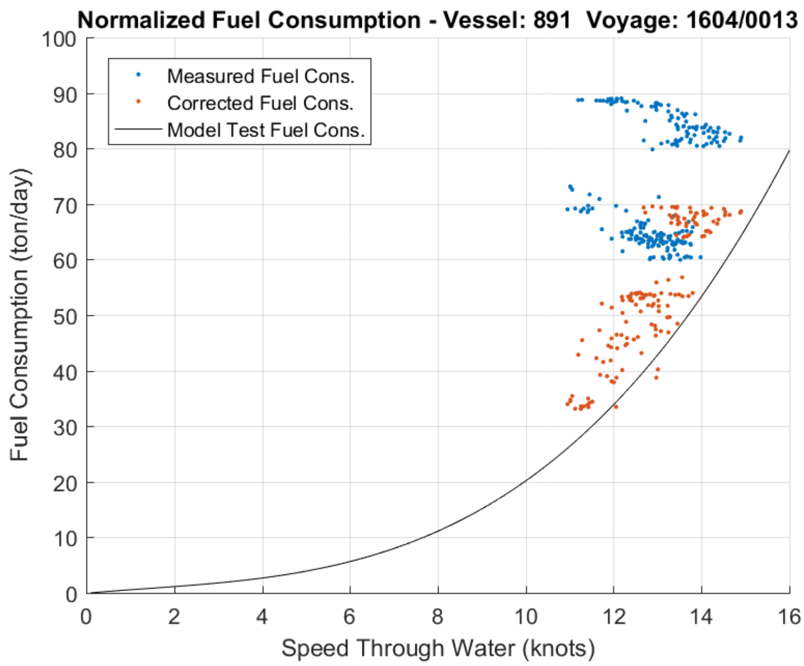
Voyage: 1603/0012 SHELL VOY





Voyage: 1604/0013





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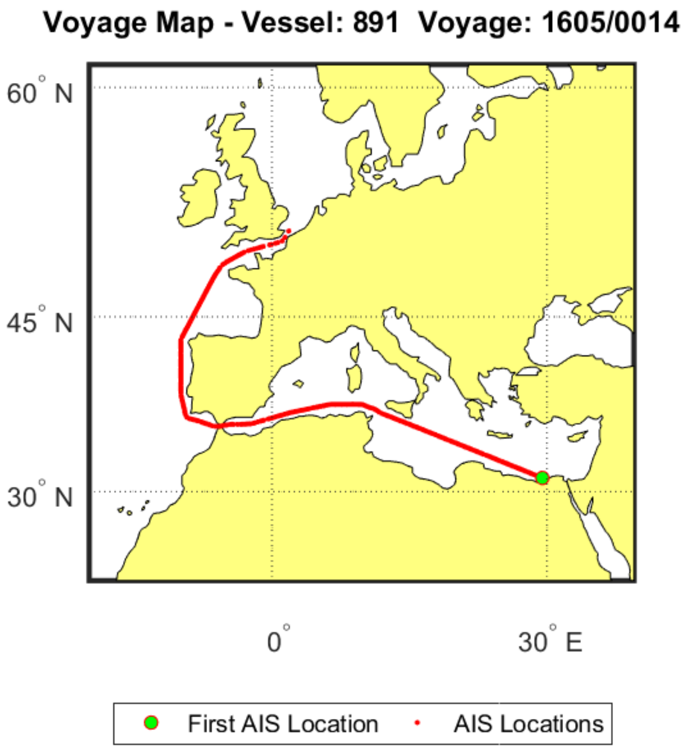

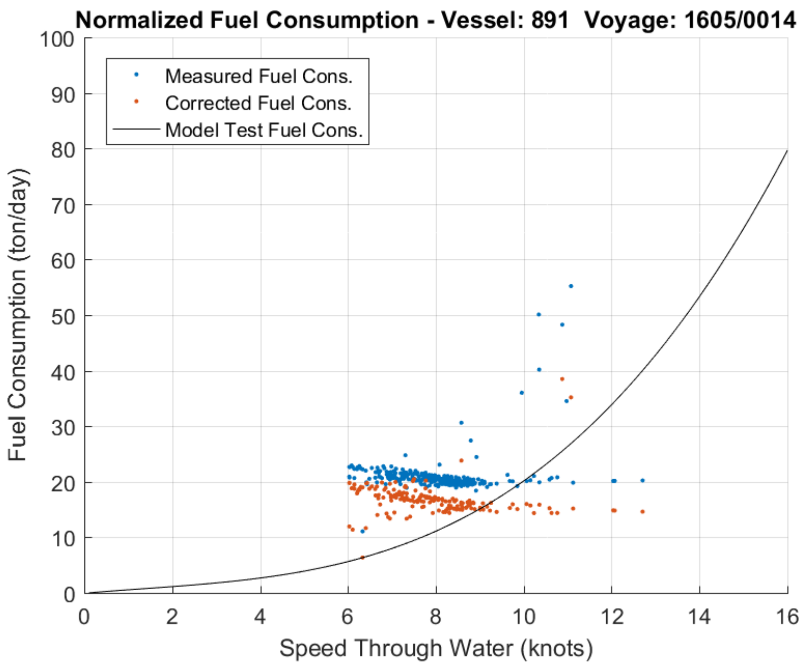

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